SCIENCE TECHNOLOGY AND SOCIETY

EDITED BY B.V. SREEKANTAN

IIAS

NIAS

SCIENCE, TECHNOLOGY AND SOCIETY

Science, Technology and Society

edited by
B.V. Sreekantan

Indian Institute of Advanced Study, Shimla
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Introduction

A three-day National Seminar on "Science, Technology and Society" was held at the National Institute of Advanced Studies, Bangalore as a collaborative venture of the Indian Institute of Advanced Studies, Shimla and the National Institute of Advanced Studies, Bangalore during 26-28 March 2006. The objective of the seminar was to bring to focus the series of problems that the Indian society is facing which are becoming more acute day by day which however can be solved or mitigated to a large extent by judicious and timely application of Science and Technology. While such a seminar naturally will have very many areas to be addressed an attempt was made in this seminar to have authentic presentations and discussions on a few of the most pressing ones. From this point of view, the seminar covered some of the high technology areas like atomic power, space technology, Health and Medicare, Genetics and Biotechnology, Modern Medicine and Surgery, New Emerging Materials Technology and developments in Electronics and Communications and Higher Education. Special efforts were made to bring in experts in these fields to make presentations on the current status of the country's efforts in these fields. *Most importantly, instead of making the discussion a closed one and only among experts in the field, an exercise which happens most often, in this seminar the active participation during the discussion time by the special invitees among whom were college students and teachers from institution in an around Bangalore, media personnel who handle S&T matters, social workers involved in missions to take science to the masses in the urban and civil areas was ensured.* Of course, there were a large number of scientists and researchers from various institutes in Bangalore too. The programme of the seminar is given in the Appendix-A, which brings out the full scope of the seminar. A brief sketch of the biodata of the eminent scientists and technologists is also presented in Appendix-B.

The inaugural session was held on the evening of 26^{th} March 2006. Extracts from the very perceptive addresses made by the dignitaries on the dais are given below.

Dr. Kasturirangan, Director, NIAS after welcoming the dignitaries on the dias, His Excellency, the Governor of Karnataka, Honourable Sri T.N. Chaturvedi, Honourable Minister for Planning, Sri Rajasekharan, Dr. Bhalchandra Mungekar, Member, Planning and also the Chairman, Indian Institute of Advanced Study, Shimla, Professor Goverdhan Mehta, other, distinguished participants, and invitees, outlined briefly the aims and objectives of NIAS. He said that the NIAS was born out of the vision of the late Bharat Ratna, Sri J.R.D. Tata who envisaged that men and women of competence and broad outlook would come together here at NIAS for a few weeks and exchange and deliberate on various issues affecting them all and listen to the ideas and views of invited distinguished faculty. It is in this perspective that the programmes of research activities, lectures, seminars, conferences etc. of NIAS have evolved over the last two decades into an institution of multi-disciplinary character. The Institute has grown from strength to strength over the years under the able and visionary leadership first of Dr. Raja Ramanna and later on, of Professor Narasimha. NIAS is continuously on the look out for appropriate themes that emphasize this important character of the Institute. In this context, Dr Rangan recalled that, about a month back when Professor Sreekantan and Professor Subbarayappa apprised him that the Indian Institute of Advanced Study, Shimla had approached them with a request for holding a national seminar on Science, Technology and Society, in which there would be scope to deliberate on the various issues of Science and Technology, how they affect the society, and look at their various dimensions, that he readily agreed to this collaborative enterprise. While India is poised for a healthy economic growth in the coming years and decades, at the same time both urban and rural societies are facing serious problems which will become more acute in the future regarding water, power, health services, education at various levels, environmental degradation, pesticide contamination in water and food products, communication, transportation, safety of individuals and institutions, and so on. It was thus decided that this seminar would look at some of the related aspects, which require the use of science-based high technologies to address these issues and problems. He mentioned that the topics that will be covered in the series of talks were those related to genetics and biotechnology, health and medical care, education, both higher and technical, environmental concerns, new technologies, high-technology electronics, communication and information technology, applications of nuclear and space technology, energy options and alternatives. He thanked the initiative and support of Professor Sreekantan and Professor Subbarayappa, for drawing up the progremme and also getting some very eminent speakers who have spent their lifetime in many of these areas. In fact, the very keynote address in inaugural session will be by Professor Goverdhan Mehta, an eminent scientist, a well-known name in the area of chemistry, who recently took over as the President of the International Council of Scientific Union, probably the second time an Indian has been honoured with the highest position in the global scientific context. He was also the former Director of the Indian Institute of Science. Dr Kasturirangan said that we were indeed fortunate to have him deliver the important keynote address that would set the trend for the deliberations on both the days of the seminar.

Dr Kasturirangan, before finishing his welcome address specially thanked His Excellency, the Governor, Sri T.N. Chaturvedi, for his presence and said that he has always shown keen interest in NIAS and has been following the developments of this Institute. He was a constant source of inspiration and advice and had been ever willing to come and participate in the deliberations.

He also thanked the Honourable Minister Sri Rajasekharan, for having come all the way from Delhi. He was a very wonderful colleague of him in the Rajya Sabha, a true Gandhian, a very modest and humble person but at the same time extremely well-informed about the issues which he was handling today in the Ministry for Planning, and he is ever interested in picking up ideas.

Dr Rangan specially thanked Dr. Bhalchandra Mungekar, Member, Planning Commission, and the Chairman of the Indian Institute of Advanced Study, which is sponsoring this Seminar, and invited him to say a few words on behalf of the Shimla Institute.

Dr. Mungekar in his welcome address as the Chairman of IIAS, Shimla thanked NIAS for responding to their request for organizing this extremely important seminar. Speaking of Shimla Institute he said, in 1964 the late Dr. Radhakrishnan dreamt of establishing an Institute of Advanced Study at Shimla, and followed it up by donating the Rashtrapati Bhavan, which was earlier Viceregal Lodge where the institute could start functioning as it is doing even now. It was planned to be a interdisciplinary research center in the country engulfing all important issues and segments of various aspects of social, cultural and political educational life of the country. Since 1964, organizing these kinds of seminars and conferences and also public lectures has been one of the most important single activity of the Institute. Dr Mungekar want on to say that the seminar of today's theme is Science, Technology and Society in which Technology has been the most important motive-or locomotive for that matter - of civilizational change. All important developments in civilization and probably culture of human society for the last thousands of years have been shaped in one way or the other by scientific discoveries, inventions and technologies. Not a single aspect of societal life has been immune and exempted and perhaps has not been developed and leveraged progressively by technology and scientific development – agriculture, industry, telecommunication, sources of energy, means of transport, education. The important contribution of technology to human society is material development. But material development is not the only objective of society. Society is based on certain immortal and eternal founding principles. Technological development is not a substitute for practising basic human values. The purpose of technology is to facilitate betterment of material conditions of life. But human life becomes rich and meaningful when we interpret it in terms of certain basic values. Such values, according to him, include democracy based on liberty, equality and fraternity, secularism, compassion, tolerance, mutual trust and respect, cooperation, character, integrity and concern for others. But in a multi-religious, multilingual and multicultural society like India it is obligatory for everyone to respect the language, religion and culture of other individuals and social groups. This requires a systematic attempt on the part of every agent of civil society to develop and nurture the sense of belonging to a composite culture. Rich and advanced countries in the world must stop adopting economic and political measures that will harm the interests of the developing countries. Today one comes across a greater divide between the rich and poor nations of the world. The divide must be bridged at the earliest. What is most important is that no country in the world, however powerful it may be, can take the liberty to intervene in the domestic affairs of other countries, let alone making aggression against them. It is in this context that a strong public opinion among scientists, technocrats, academicians and intellectuals at the world level must be created opposing any design of putting humanity either partly or wholly into the danger of war.

Quoting Dr. Sarvepalli Radhakrishnan, Dr. Mungekar said "It is not possible for us to gain universal brotherhood unless you transform the nature of man, unless you are able to depend not merely on the external structure but on the inward soul, unless we are able to feel in the pulse of our brain that we all belong to one human race, unless we are able to transcend our group loyalties and acknowledge the primacy of the human race".

Hon. M. V. Rajasekharan the Chief Guest of the function - started his address with a quotation from Gurudev Rabindranath Tagore: "I slept and dreamt that life was joy. I awoke and saw that life was service. I acted and behold! Service was joy." In the modern-day world expectations from Science and Technology, are getting higher and higher. Science and Technology is called upon to provide solutions to almost all the problems faced by society. Science and Technology is an important vehicle for growth and development of our society. India, is one of the top-ranking countries in the field of basic research in Science and Technology. Science in India has come to be regarded as one of the most powerful instruments of growth and development, especially in the emerging scenario of competitive global economy. Since time immemorial India has been utilizing traditional scientific knowledge. And the application of modern scientific knowledge has helped to overcome many difficult problems, for example invention of lifesaving drugs, telemedicine, tele-education, satellite-based development of communication network, and the agricultural revolution have brought much relief to our people. At the onset of Independence, the first Prime Minister of free India, Pandit Jawaharlal Nehru, called science the very texture of life, and optimistically declared, "Science alone can solve problems of hunger and poverty, of insanitation and illiteracy, of superstition and deadening customs". Under his leadership the Government of India set off to address the numerous problems of society. The green revolution, improvement in educational standards, establishment of scientific laboratories, IITs, and setting up of premier scientific institutions such as the Council of Scientific and Industrial Research, Atomic Energy Commission, National Physical Laboratory, National Chemical Laboratory, Indian Agricultural Research Institute, launching of massive hydroelectric projects and entry into the frontiers of Space, all evolved from his early decision to embrace high technology. He was able to usher in the scientific revolution in our country and laid the foundation for scientific and technological development, which few other earlier colonial countries ever achieved in a single span of lifetime. During the last sixty years or so the country has built a number of scientific and educational institutions. Today the country has the largest technical and scientific manpower, reasonably self-sufficient in food production and done well in milk production. Accomplishment in Space Technology, Atomic Energy, Biotechnology, and Defence Research have been remarkable. With economic reforms already in progress our industry and trade are moving in the right direction to reach the developed country status in the near future, provided a powerful technology base is prepared. Mahatma Gandhi had always emphasized making villages self-sufficient to meet their daily needs, including empowering them to become village republics. Now, the most modern tools of information technology, biotechnology and knowledge systems may be employed to achieve his dreams. There is a need to intelligently integrate ideas and design a management strategy to develop a strong rural technology base in agriculture and non-agriculture, and specially in infrastructure-cum-service sectors. Setting up of more and more rural technology-based rural enterprises will not only upgrade human skills, generate employment and create wealth, but will usher in an era of growth, development and other opportunities for our people. This will necessitate a radical change of mindset and a strong belief in innovativeness and management of changed concepts. If there is a quest for scientific and technological discoveries, then equally important is to generate a quest for applications of various technological innovations for benefiting the rural masses at the grassroots level, for overall improvement in their lifestyle and surrounding conditions in rural areas. To achieve this, as Gandhiji said, "Put the people at the center of every development". The Minister pointed out that recognizing the importance of knowledge in this globalising world, the Honorable Prime Minister Dr. Manmohan Singh had set up a National Knowledge Commission to develop new concepts for higher education, boost research and development activities in science and technology and institutions and to increase the competitiveness of domestic industry in the years ahead. Then the Hon. Minister Sri M.V. Rajasekharan highlighted the progressive role of the UPA government in giving emphasis to rural development through scientific interventions and implementing programmes. And in the national Common Minimum Programme. He also stated that the UPA government will follow policies and introduce programmes to strengthen India's vast science and technology infrastructure. Science and technology development and application missions will be launched in key areas covering both global leadership and local transformation.

Finally, the minister pointed out that the economic growth of India, particularly rural India, needs a unique model of employment-oriented growth and calls for a new scientific and technological order which promotes rural production for urban, metro and global consumption through application of innovative technology with low investment.

He closed his address with a quotation from Mahatma Gandhi referring to seven social sins afflicting our present society – "politics without principles, wealth without work, commerce without morality, education without character, pleasure without consciousness, science without humanity, worship without sacrifice".

His Excellency Sri T.N. Chaturvedi in his inaugural address said he would like to congratulate both the Indian Institute of Advanced Study, Shimla, whose Chairman happens to be with us here this afternoon and the NIAS for this kind of a collaborative effort. He was aware that NIAS had been making a number of collaborative efforts of this kind and ventures of this type which really indicate, the interdisciplinary and the multidisciplinary requirements of a knowledge society or of knowledge itself. The Shimla institute was set up because of the visions of Dr. Radhakrishnan and Pandit Jawaharlal Nehru and similarly this Institute, NIAS, owes its inception to the vision and the farsightedness of Sri J.R.D. Tata. This seminar assumes importance because its subject is Science, Technology and Society. One can say that it is just a reassessment, a summing up at a very crucial period of our national life of the role that science and technology will play in the transformation and development processes of the country.

He recalled the opportunity he had to be associated with the Indian Institute of Advanced Study, Shimla when the first review committee was established, with the eminent archaeologist and historian Dr. Sankalia as the Chairman and Professor A.K. Das Gupta, the eminent economist, as a member. He happened to be a member of that review committee sometime in 1978. And he said that with some amount of pride and with due humility he would like to submit that he had some role to play through a supplementary note of his as a member of that committee when the Institute was in the doldrums, and he sometimes felt happy when his note is quoted in the documents of the Indian Institute of Advanced Study, though it has not been possible for him to visit that Institute since then. But he is aware that, like NIAS here, the Institute has been doing a lot of publications and holding a number of seminars and probably that was the idea of Nehru and Dr. Radhakrishnan who initially decided to have an Institute of this kind on the model of Princeton, etc. He finds this seminar very interesting because one of the important things is that the effort is to bring in the members of the civil society, NGOs, the other interested people, and not just a seminar of only the professionals and the experts or the scientists themselves but in order to spread the awareness wider, to bring in and ensure the involvement of the society at large, the effort is being made in this particular seminar. The programme that has been worked out has been very imaginatively designed. I think there is hardly any aspect of science in relation to development, which will not be covered in this seminar. So far as India is concerned the Governer said all of us are aware that we have a rich cultural tradition in the country not only in arts, literature, philosophy, and religion but also in science, along with China, where a lot of work was done as portrayed by Professor Joseph Needham.

The Governer said in the development of science in this country five phases are extremely important. The first phase is a part and parcel of what may be called the Indian Renaissance. This Renaissance was not confined only to Bengal, though it had its beginnings there. It spread to the other two Presidencies, that is

Bombay and Madras, and it had its glimmerings in different parts of the country. The second phase was the Swadeshi movement, when the Indian Institute of Science was conceived by J.N. Tata – another upsurge in our history, reclaiming our sense of national pride. Here, one can say that nationalism, patriotism and the scientific spirit got intertwined. The third phase, one may say, was the development that took place during the two World Wars, particularly the Second World War, which affected the country willy-nilly because it was under colonial rule. And as Gandhiji said, the world was never the same after the holocaust, Nagasaki and Hiroshima. In any case, it gave a fillip to the development of science and technology in this country. The fourth phase was the post-Independence period, again under the leadership of Nehru with the vision he had of science and technology in this country. We know the wonderful story of institution building and the people who contributed to the growth and the development of institutions. The fifth, his Excellency said, is the last twenty-five or thirty years when there is a feeling that India is emerging as a knowledge society, as a scientific power, as a nuclear power, an economic power, and so on. This is another assertion of the spirit in this country for development and it is important that this kind of important seminar which is being held to show what this country is thinking of in the eleventh plan and what has been done. That is why it is a question of taking stock of what can be done about the problems which were mentioned by the two earlier speakers, the Minister for Planning and the Member of the Planning Commission - the development of frontier technology, nuclear science, Space science, electronics, IT, BT and nanotechnolgy. Science and technology have made an impact on society. There is no area of life which will be left untouched in the years to come and that is why the Honourable Minister rightly quoted Pandit Nehru as saying that science is the instrument of development and will solve all the problems in every sphere. The impact of science and technology is significant even on the subject of education, higher education and science education, which is fundamental and basic to development of science and technology and even society. Science will transform society and already we are feeling its impact on the economy, polity and society. And that is why it is good to find that we will be discussing in this Seminar, the role of education and the problems and issues relating to higher education and science education. The Governor pointed out that at least some thought ought to be given to the problems of primary and secondary education, of foundational education. Again, the role of science and technology in bridging the economic or the social divide which Dr. Mungekar talked about, is important. One of the things which has recently come up is the question of shortage of teachers, particularly in the field of higher education – in IITs and so on. These problems have been highlighted in the hope that they will be dealt with in this seminar. Our achievements, aspirations have exceeded our expectations but much more requires to be done. So how can this problem be solved? The problem that has been heard here and elsewhere and even in Parliament at some point of time is the question of the fundamental sciences and the applied sciences and so on, and how to attract youngsters. The government is doing something about them. That is why it is a question of stocktaking, assessing the lacunae to be overcome and inadequacy to be made up.

The Governor then emphasized the role not only of the State and the Central government but that also of Industry and the Corporate sector. The Prime Minister mentioned at a meeting that privatization of education is much too early. He may have his own viewpoint but then the question of partnership is very necessary. Unless business, industry, the corporate sectors also extend their support it will be very difficult to solve these problems. As far as the State is concerned, its role in this naturally has to diminish. The role of the State in many sectors has to be redefined. But that of course, doesn't mean that the lesser government or the lesser the role of the State does not necessarily imply an indifferent State or an indifferent government. They have to take into account the totality of the problem and the society we live in.

In this State of Karnataka the very many great Dewans like Seshadri Iyer, Sir M.V. and Mizra Ismail worked out the concept of co-partnership. So we have to think of the ethical issues, not only of science but also of education and also the social issues – how they can be tackled in this concept of partnership and when responsibility is also assumed by the private sector. As Nehru said, there is nothing like private or public sector, there is the national sector, the society as a whole. The AICTE, the UGC have been thinking of these things and some of the best minds in the country are here to discuss these issues and could keep these thoughts in mind, participating in this seminar now with many people who are working in this field.

Talking of the new developments like Edusat, telemedicine, genetics, biotechnology, the Governer cautioned that there are negative and positive aspects, controversies over seeds etc to be taken note of. So much has been said about rural India and urban India and taking health and medicare to rural India. Urban India is only a continuum of rural India and rural poverty. We should take a comprehensive, not confrontational view. Ecology and the environment have to be considered. The word 'environment-friendly' is used in the context of applications of nuclear technology. Fossil fuels are getting exhausted and other energy options have to be considered. Who knows these problems better than those who are sitting here and participating? All this makes this seminar very important. The message, is that not just compilation of scientific facts but the people have to be prepared for meeting the future. How we carry health, education facilities to the people, is a problem whose solution has been eluding us all these years. Science is a blessing but it could be a curse depending on how we use it – the ethical and moral issues, not only in research but also elsewhere. Not only our country but the whole world is concerned with moral and ethical issues. The help of the Indian pharmaceutical industry is being sought in one of the African countries in treating AIDS and HIV. This is something that is very exhilarating to each and every one of us but that also shows what the possibilities are there for the country.

It is good to see that in our country science is not confined to the various institutes but there is so much of interaction between various institutions of higher learning and scientific learning and universities because we have to attract and pool the talent in this country and achieve much closer coordination between science departments and other institutions of higher sciences. It is heartening to find that the Indian Institute of Science is now collaborating with the Mysore University and setting up a campus there. This kind of an inclusiveness and interaction, will greatly help to solve many of our problems not only of science, education and research but also in taking social issues to the people.

The Governor wished the seminar all success.

Apart from the fact that the seminar itself provided an occasion for free and frank discussion on the various issues, one very desirable and welcome outcome was that practically all the speakers provided the written versions of their presentations. In this volume, these presentations which have a rich content of valuable and authentic information with a portrayal of the future plans of the governmental agencies and definition of those that need to be shared and implemented by other non-governmental agencies. We do hope it will be a valuable addition to the books and proceedings of other similar conferences held earlier that have already appealed. I would like to thank Prof. B V Subbarayappa for the encouragement he gave for undertaking the organization of this seminar by NIAS and also in advising us on the possible speakers on the various topics. I would also like to thank Prof. Bhuvan Chandel who was the Director of the Institute of Advanced Study, Shimla when the proposal for this collaborative seminar was mooted and for suggesting that this should be held at the National Institute of Advanced Studies, Bangalore.

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Emerging Technology of MEMS and Indian Initiatives

V K AATRE

Good afternoon. It is normally not a good practice to start a lecture with an apology. Unfortunately I am forced to do that for the simple reason I don't work in this field. I don't do research in the field of MEMS or smart materials. But somehow I got into this area in trying to design certain acoustic absorbers for an underwater vehicle. I ran into a chiral material. While discussing with experts in this field, I heard about a new fields – the emerging field of smart materials and MEMS, which I shall explain to you. And later on, in the early nineties I happened to get involved in organizing the first course on Smart Structures and MEMS at the Indian Institute of Science. Since then I have been deeply involved in this very highly application–oriented technology. I had the good fortune to run a National Program, for all the scientific departments - DRDO, DST, DOS, CSIR, Department of IT. To some extent DRDO have been instrumental in starting a Society for Smart Materials and Structures based around the Indian Institute of Science. The Indian Institute of Science is very active in the R&D aspects of this field and we are trying to look at industrial application and product development embedding MEMS and smart materials. I could have talked to you about Light Combat Aircrafts, Submarine systems or Oceanography, which I am more familiar with. However, I thought I should introduce you to this emerging technology.

What is this smart material? Why is it we are talking about smart materials? If you look back at the development of technology itself in the last century or in the last fifty years of that century, most of the electronics and machines were developed using materials which had normal properties like weight-bearing capacity, tensile strength, ductility, malleability, and so on; but none of them really interacted with the environment. Can we somehow design materials which interact with the environment and change their properties with the change in environment or adopt to the environment? Think of chameleon which adopts its colour to (Fig. 1) the environment. The touch-me-not – or in Kannada we call it '*muttidare muni'* - closes its leaves if you touch it. Why should it close? It is reacting to the environment. Should we not call it smart. Can we design such systems – the smart systems. And then insects. One of the most fascinating creatures with Unconventional aerodynamics. They flap their wings. And morphs their wings. Can we design systems of this kind? Some of these things could be done by using these smart material structures.

Let me give you two examples before talking about the materials themselves. I have shown a robotic hand (Fig. 2). These days we hear about robotic surgery. The doctor performing the surgery would like to know the structure of the tissue the robotic hand is encountering, which can be inferred by force feedback. Just imagine that you are holding something in your hand. What

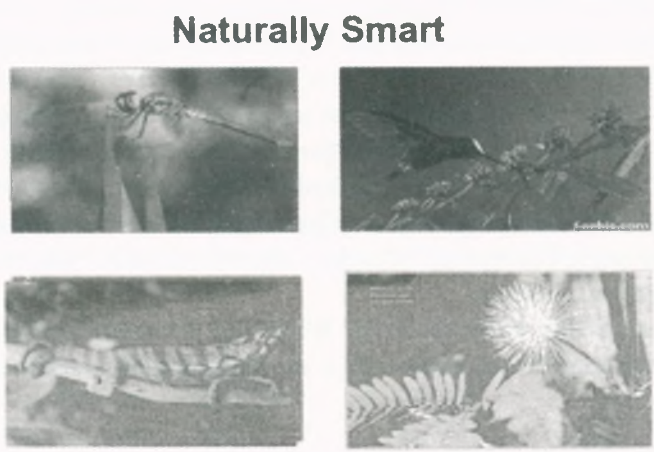


Fig. 1

happens? At the tip of the fingers we have tactile sensors – touch-sensitive sensors. When you press, there is a force feedback, which is conveyed by the neural systems to your brain which somehow analyses the force feed back. If you are holding a rock, the force-feedback would be very high. And on the other hand if you are holding a sponge, the force will be small. On the other hand if you are holding an egg, it will tell you when not to press any further. Can we design systems which such touch sensors? If we could, look at the application potential, the answer is that we can build such systems. We are trying to build laparoscopic surgery instruments where we need such force feedback systems. though not for full robotic surgery.

In India we have many old bridges. Can we monitor their health. Suppose there is a wall and there is a crack in the wall. If it is an interior crack, we will not be able to recognize the crack till it manifests as a surface phenomenon and it may be too late to take any action. If we can, we recognize it at the initiation of the crack itself then it may be possible to correct it. Fiber optic sensors can be embedded in structures like this and monitor their health. In universities like Stanford they have demonstrated this and went a step further - “self-healing bridges”. Whenever there is recognition of a crack, we can embed a vial, which gets punctured and a jelly in that vial flows into the crack and fills it. No, this may

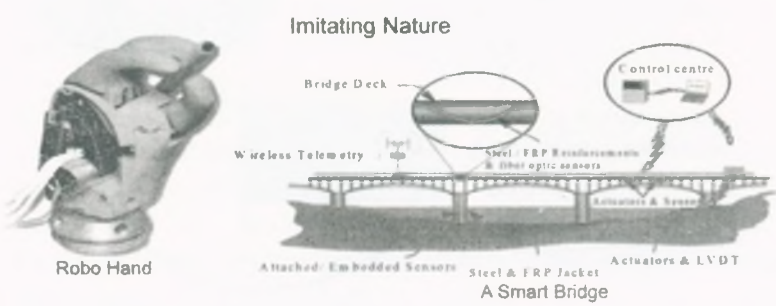


Fig. 2

not be a permanent solution but at least, it has initiated action to prevent further damage. In India we have started such an activity to monitor the health of the bridges.

But what does all this mean? Suppose we can build a system which can embed both a sensor (which is normally gives a electrical output to an mechanical input), an actuator (which normally implies a mechanical output to an electrical input) and the required control and communication electronics in a single chip, we can build a Micro electro mechanical system. In addition we can have materials which interact with the environment – materials which change their properties due to temperature changes, change in stress, viscosity, or changes its properties because of the dampness, we have a Smart System (Fig. 3). Suppose you can think of a gel which can absorb moisture and increase its volume and reduce its volume when it is dry, we can build 'locomotion' using such gel. And control it.

We should not define 'smart materials' as if we define 'smartness' in human beings. Smart materials somehow react with the

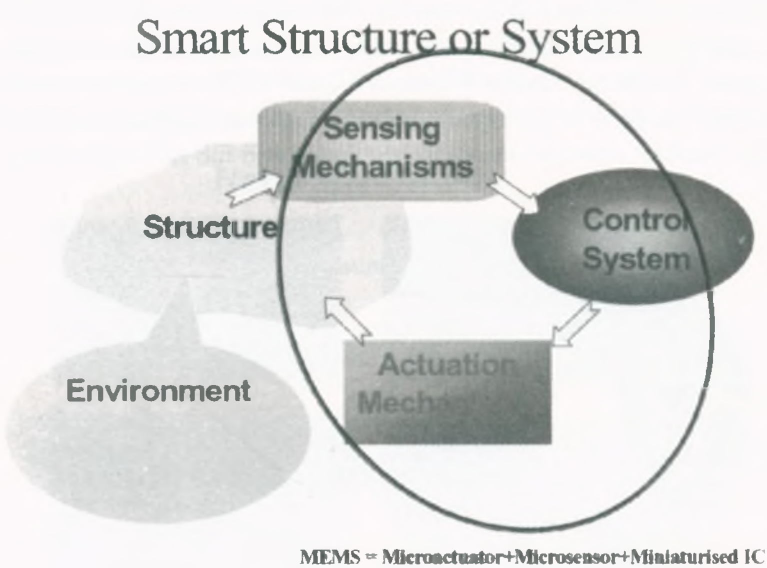


Fig. 3

environment, adjusting their properties to the environment. Remember, a decade or earlier, children used to play with toys – toys which when put in a frig change their colour; or T-shirts that change their colour when you blow on it. Such is the field which I want to talk to you this morning – a system which has sensing mechanism, an actuating mechanism, control mechanism. Obviously, if we are going to build such a system for say health monitoring a bridge, they have to miniaturized so that they should not interfere with the structural integrity of the structure itself when embedded in the structure. It must not change the properties of the structure.

We have developed excellent silicon technology and micro electronics. Now we are looking miniaturization of mechanical components – beams, cantilevers, gears, motors, pumps, micro fluid systems etc. We would like to extend this technology beyond silicon and to include other metals and materials like polymers. We are expanding the horizon materials to include electorstrictive, magnetostrictive, rheological, thermoresponsive, electro-chromic, shape memory materials. These materials can be used for either sensing or actuating.

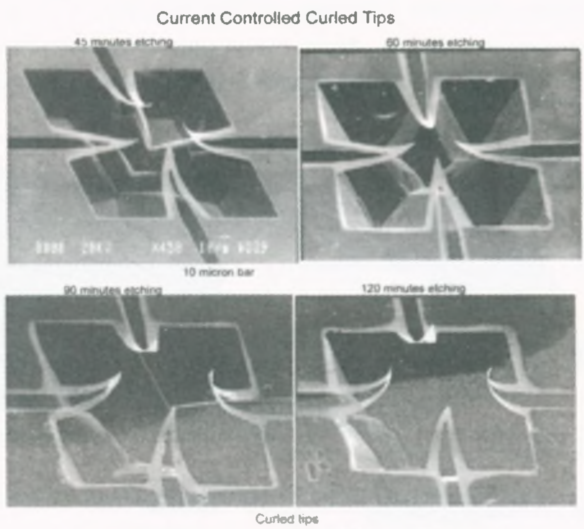
The first micro-machine was built several decades back - a motor built using Piezo-electric material. Piezoelectric is perhaps, the first smart materials we knew. Materials like quartz, lead zirconate titanate, barium titanate produce mechanical strain on application of electric voltage and vice versa. In fact, I have been using such material for developing under water transducers for decades. And today many of the smart systems use a piezo-ceramic material. The first motor was built like a standard motor with a rotor and a stator, rotating at very large rpm. Obviously such motors cannot be used for power generation. Can we find uses for such micro motors and find an application where hundreds of them can be used for a specific purpose? Remember how ants carry a long stick whose weight is perhaps more than the combined weight of the ants. This is multiplicity in action. When we build micro-systems, we can use such multiplicity to produce amazing results.

Some times such micro technology is called M-cubed technology – Micro, Multiplicity and Multidisciplinary.

I do not want to overstress the application potential of MEMS, Smart System; or in general Micro-systems. Such technology uses many more materials than piezo materials – polymers, electro-conductive polymers, electro-active polymers. MEMS have given raise to MOMS (micro-opto-mechanical systems), and MOEMS (micro-opto-electro-mechanical systems). Remember that today almost every thing can be miniaturized. Bulk properties of materials still hold at the micro level unlike Nano material where we are (almost) operating at the molecular level and the properties at the molecular level are not necessarily similar to the bulk properties., whereas here we are not going to that level. The bulk properties of the material still hold.

Micro machining technology is fundamentally based on the already well developed Silicon technology. We have been using such technology for producing micro electronic chips (VLSIs, ASICS, MMICs, etc.) for nearly fifteen years and now we can pack a million transistors on a single chip. We know how to handle the microcircuits. If we can extend this IC-technology to mechanical components we can build micro-sensors, micro-actuators or in general micro systems. With such systems we can well imagine the areas of applications – aero space and defence, automotive sensors and electronic systems, communication, biological and health sciences (bio-MEMS), structural health monitoring, data storage, ink-jet printers, micro-fluidics, micro mirrors etc; application is limited by the individuals ingenuity and innovativeness. In my opinion, there is not a single field where such technology is not applicable. We in India missed the silicon technology but we should not this micro system technology. This revolution is only a decade, or a decade and a half old, and we have been working on it for about five to six years. So we are not that far behind the world scenario. If we miss this revolution also, I think we would have missed most of the main technological revolutions. That is why this group of ours is trying to spread this technology of Smart Systems and MEMS. Several institutions - IISc, TIFR, IITs, NAL, several DRDO laboratories, ADA, ISRO, several CSIR laboratories - are working in this area and on wide variety of materials – piezoelectric, electro and magneto strictive, polymers, polymer gels, optical films, electro and magneto rheological fluids, shape memory alloys – and started developing devices and products.

Silicon micromachining uses what photolithography and a number of other allied technologies use. Micromachining technique itself is slightly different from the silicon technology. A silicon foundry cannot be directly used as a micromachining foundry. In micromachining we have both surface and bulk micromachining techniques. Details can be found elsewhere. However, it is sufficient for us to know that through these techniques we have been able to fabricate micro mechanical systems like micro cantilever. Many application need such cantilevers. We are planning to use this in a biomedical application. All India Institute of Medical Sciences, IIT Delhi, IIT Bombay are together



Current controlled SiO_2 Curl Tips are fabricated using micromachining techniques
Curling of tips takes place due to bi-metallic stress (metal on SiO_2) during fabrication
Uncurling takes place by passing control current of 1-15mA

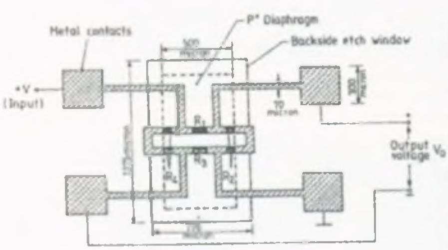
Fig. 4

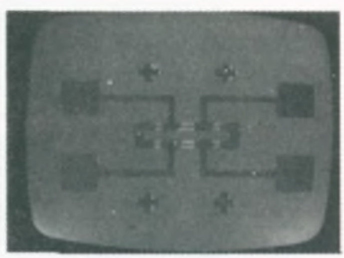
designing a TB diagnostic chip using such cantilevers. By coating the cantilevers – which are 0.5 to1 micron thick – with certain antigens or chemicals we can develop diagnostic kits (for medical applications) or gas detection kits (for pollution and environmental monitoring). Besides cantilevers, we have micro machined beams, spirals, gears, tongues, motors etc at various academic institutions in India. For example at TIFR we have fabricated a system with four tongues or curlers (Fig. 4) which on application of electrical field can curl in or out.

Micro accelerometers. pressure sensors find very wide application in automobiles – anti-collision airbag sensors, tire pressure sensors, manifold pressure sensors etc. IIT, Chennai has built such sensors and Bharat Electronics has packaged the same (Fig. 5). One of the first Micro systems fabrication was attempted at Solid State Physics laboratory of DRDO – a possible micro flow meter to detect and measure minute amount of gases. One can build other kinds of microstructures including RF MEMS - radio frequency micro-electro-mechanical systems. We build inductors, capacitors, transmission lines, wave guides etc. Such work is being done at IIT, Delhi and BEL. .

Let me say few words about rheological fluids, where we can control the viscosity by applying either electrical or magnetic fields.

Pressure Sensor





LPCVD Polysilicon Piezo-resistors on thermally grown SiO_2 diaphragm realised by KOH anisotropic etching and boron etch-stop technique.

Boron doping concentration in polysilicon resistors is adjusted to make temperature coefficient of resistivity near zero.

Fig. 5

The potential application of such viscosity control in shock absorbers is clear. Such shock absorbers or far superior to the mechanical ones because of the speed of operation. Suppose you can Such kind of work is in initial stages in India. Concept demonstration has been done at NPOL, DRDO using suspending carbonyl iron particles in castor oil and demonstration of viscosity control, and non-arching switch has been done.

Smart systems and MEMS have very wide application in military systems (Fig. 6). For example, in rotor crafts, largest amount of noise comes because of the flexing of the rotor blades. Buy introducing certain micro sensors – and of course, building the required electronic control systems along with them we can reduce the noise. Indeed vibration suppression systems is an important application of MEMS. Another major envisaged application in aero structures. If we want to build micro air vehicles (insect like vehicles) we need build wings which can change their shape, thickness and contour during flight. We are about to mount such a program in India.

MEMS also find application in medical and health sciences. One major potential application is in Drug delivery systems. Today

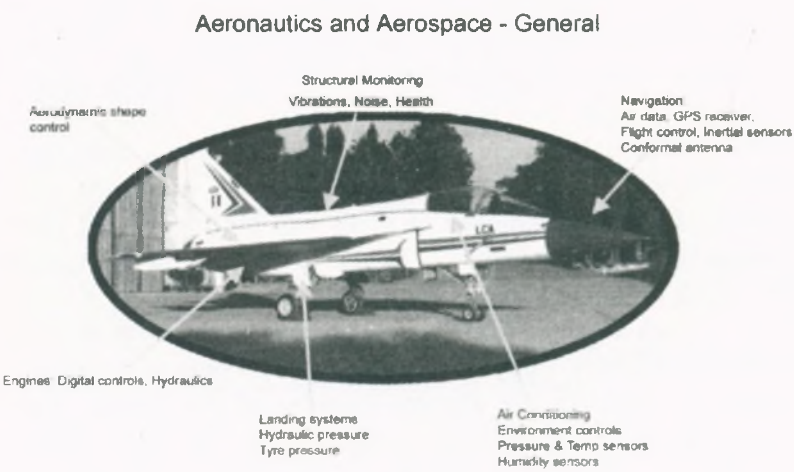


Fig. 6

chemotherapy for cancer (some believe that chemotherapy is nearly as dangerous the disease itself) may do some damage to the cells surrounding the cancer cell. The question is whether we can design drug delivery system that can be aimed at the specific cells only. Of course, we are still to do lot of work to achieve this. We may have to resort to nano technology to achieve this rather than micro systems technology. (Though I am not going to talk about Nano science or technology, let me digress a little. A few decades ago ago, there was a movie called "Fantastic Voyage". A military General has a cerebral thrombosis in an area which is impossible to be operated in the normal way. Few brilliant scientists decide to miniaturizes (nano!) a submarine along with three medical personal people and injects the whole thing into the General veins. This nano submarine navigates to the specific location of the brain and the operation is successfully performed. Science fiction! Yes. But we must remember to-days science fiction may become tomorrows realities. There are sufficient instances for this. If we read books from Eric Drexler's 'Engines of Creation' - where he talks about molecular assemblers and self replicating nano robots – or Michael Crichton's 'Prey' - where he paints a scary picture of such a happening, one wonders about scientific inventions and technological innovations. But we must also remember that technology is a dual-edged sword. It can be used or abused; abused intentionally or otherwise. Nothing comes without risk.) We have mounted a program for a drug delivery system - insulin dispensing. India will have the dubious distinction of having forty per cent of the world's diabetics within the next few years. A large number of them will be uneducated (and perhaps illiterate) and would not be able to carryout the instruction for taking insulin. An insulin dispensing system would be a boon (Fig. 7). Such a system which perhaps packed in the form of wrist watch would carry a micro needle to extract a drop of blood and sensor to measure the glucose content of the blood; then depending on the requirement a micro pump and fluidic system would inject insulin – carried in a micro vial – at the required

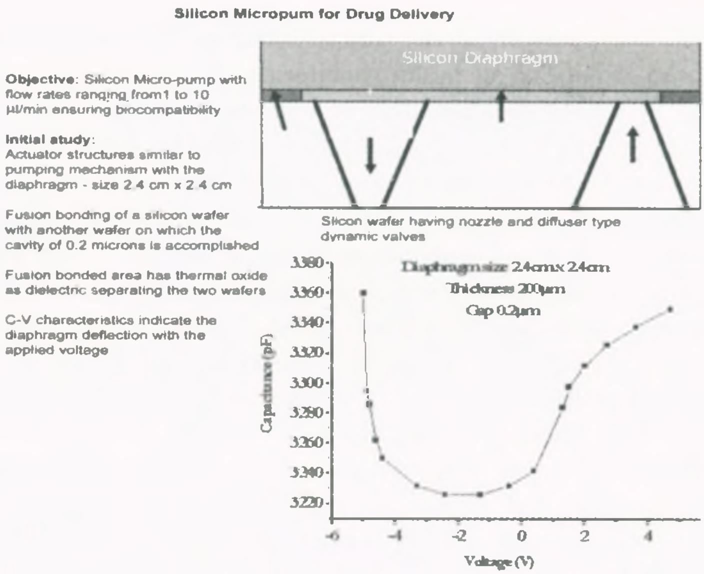


Fig. 7

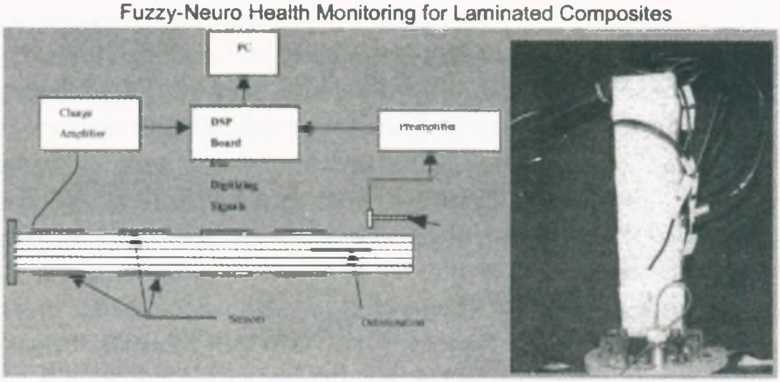
rate. There are a number of problems to be solved including that of a micro battery to power the whole device before such a thing becomes a reality.

Damping unwanted sound is very important. One of the first things in demonstration of smart systems I saw was that of Smart Wall Paper which can be pasted on to the walls to render the room nearly sound proof. I have listed all these examples to indicate that the vast scope of this technology. Virtually nothing seems to be impossible. Application are spread from aero space to automotive application, from structural health monitoring to smart bridges, from diagnostic systems to drug delivery systems, from smart shoes to smart cosmetics; only limited by our ingenuity and innovativeness.

As indicated earlier Structural Health monitoring in an important area of application of MEMS. The Structural Engineering Research Centre of Chennai has embedded sensors (externally) to monitor the health of a bridge in Vizag (for monitoring the health of structures sensors should actually embedded internally at the time of erecting the structures). We are also looking in to health monitoring of composite structures (Fig. 8) where delamination is a major problem. This is an important issue in Light Combat Aircraft which has 40% composites in its structural material. Vibration suppression is another area of application. At the laboratory level we have obtained encouraging results in vibration suppression by using MEMS. Many other applications like flutter control are possible application and NAL is looking in to several of them. In an aircraft it is important to measure the pressure across the aerofoil section *in situ*. We are planning to implement such a scheme in LCA through MEMS sensor tapes which are being fabricated at BEL.

With such a vast field of application, we have taken certain steps in India. It all started with an International Conference on Smart Materials and MEMS conducted in 1996 in collaboration with SPIE. At that stage only 10% of all the papers presented were from India. In 2005, last July, when we conducted the Fourth Conference of this series 65 per cent of the papers were from India. This happened due to two factors – formation of Institute of Smart Materials and Structures (ISSS) and a National Program on Smart Materials (NPSM). NPSM was run by DRDO through

Fuzzy-Neuro Health Monitoring for Laminated Composites



Damage detection through artificial neural network (ANN) using dynamic response
ANN is trained to recognize the known patterns and classify the data based on these patterns

Fig. 8

ADA and supported by the five scientific departments – DRDO, CSIR, DOS, DST and DIT. Through this program we have established design centers across India, mounted R&D programs in materials, devices and packaging, established fabrication center for MEMS, sensitized various communities – academic, research and industrial – about this field, and conducted manpower development programs. The CAD Centre was initially established at the Indian Institute of Science and today we have 19 centers operating in India. The SCL I micron silicon foundry has been expanded to fabricate MEMS. We have also established a packaging facility at BEL. All in all NPSM has been successful program in establishing this highly application oriented area of smart and micro systems (Fig.9).

With the kind of enthusiasm it has generated and the wide spread research and development work taking place in materials and devices in the area of micro systems, I would only hope that we do not miss the revolution taking place in the area of Smart Systems and MEMS.

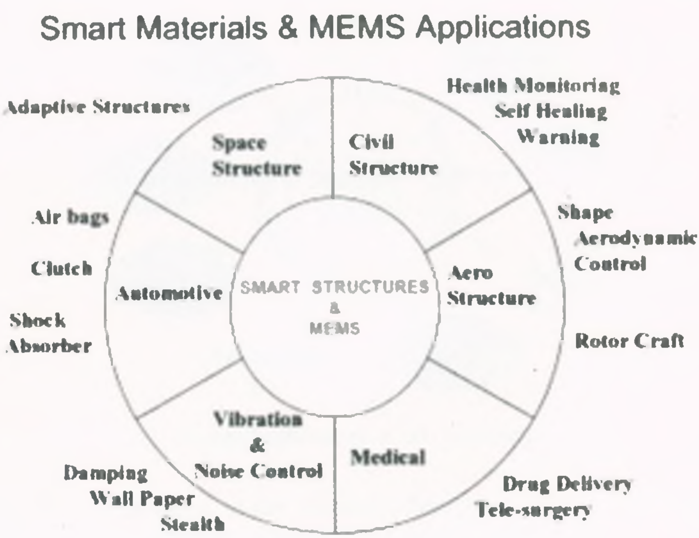
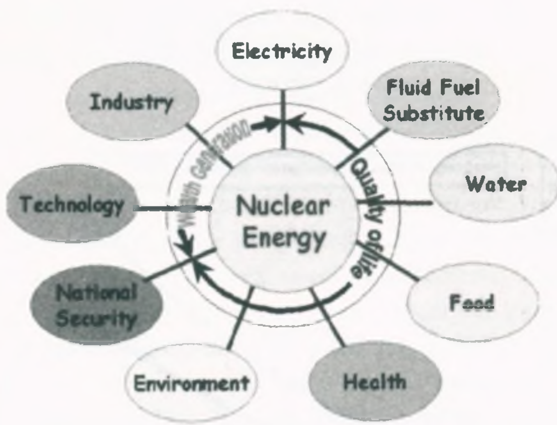


Fig. 9

Applications Of Nuclear Technologies For Societal Benefits[1]

SRIKUMAR BANERJEE

Let me first thank the organizers for giving me this opportunity to talk to you about how exactly nuclear technologies are related to societal benefits. The first part of my talk will be about nuclear power generation, which is our primary concern. Then I will go over to the non-power applications of radiation and isotope technologies. There we will see the coverage on healthcare, food irradiation and agriculture, water desalination, and urban and rural waste management. I shall also touch upon some of the spin-off technologies.



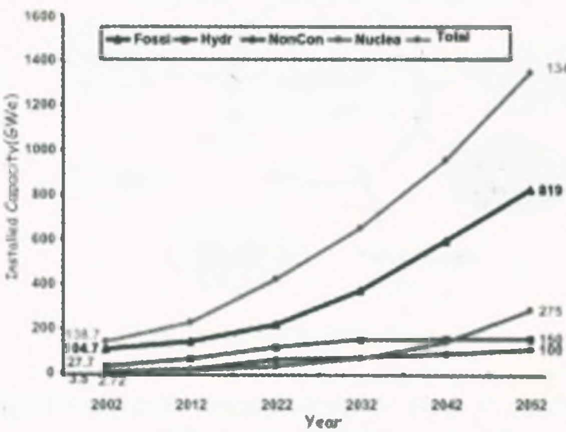
Various Applications of Nuclear Energy

[1]Based on a talk given in the "National Seminar on Science, Technology and Society", NIAS, Bangalore, 26-28 March, 2006

1. ENERGY NEEDS

India needs to increase the per capita power consumption which has a direct relationship with the quality of life of its people. Our per capita electricity consumption is close to 600 kWh where as it is nearly 13000 kWh in the USA. To realize high growth rate in our economy - which is typically at the level of 7-8% today, and can touch 9-10% very soon, we need to grow our electricity generation capacity at a very fast rate. What is being projected is that there will be something like a tenfold increase in the installed capacity reaching up to 1300 Giga Watt electrical (GWe) in India by 2050.

We have been considering all possible sources of energy – fossil fuels, hydro-electricity, non-conventional energy and the nuclear energy to reach this installed capacity of 1300 GWe by 2050. Out of this, we shall be reaching the maximum of hydro-electric potential soon which will be about 150 GWe. The non-conventional component would at best grow to 100 GWe. The fossil fuels, which form the main component today, may be scaled up to 800 GWe. Therefore, it is necessary to raise nuclear power in the next 50 years to about 275 GWe. This will correspond to 20-25% of the total installed capacity.



Projected growth in installed capacity

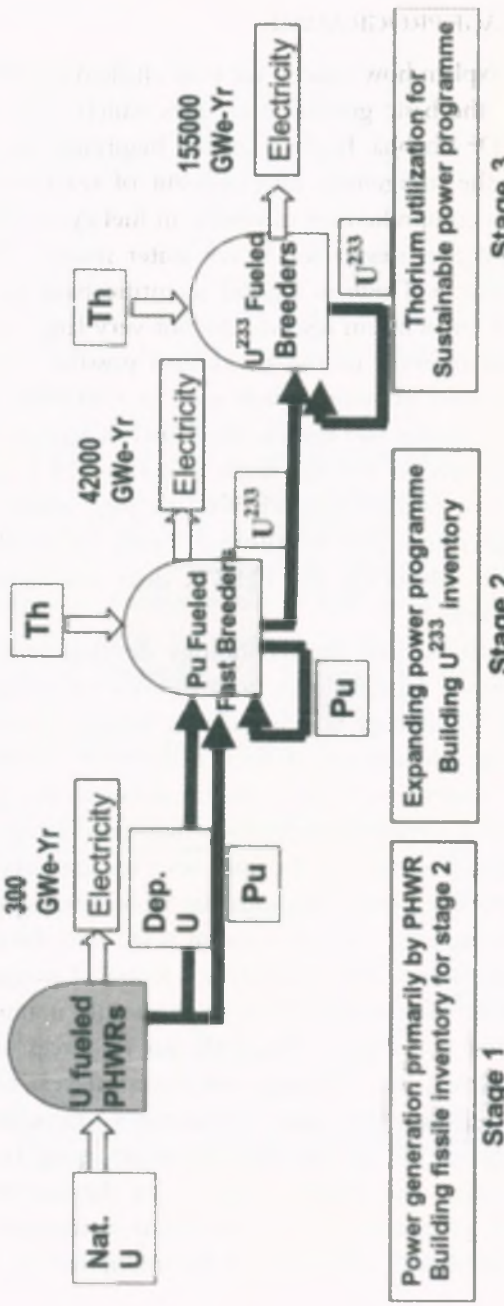
2.THREE-STAGE PROGRAMME

Now let me explain how exactly we have chalked out our program and what are the basic guiding principles which were thought of long ago by Dr Bhabha. Right from the beginning we have been working for the indigenous development of reactor technology and building a comprehensive capability in fuel cycle technologies.

We selected the pressurized heavy water reactor (PHWR) as the reactor system. There is a good scientific basis for choosing the PHWR. Our uranium reserves are not very large and we have to utilize this reserves to the maximum possible extent. Each kilogram of mined uranium is best used in a PHWR because of the neutron economy and the excellent fuel management possible in this type of reactor and the fissile uranium-235 is used to the maximum extent. Secondly, the PHWR is a good system to convert the fertile uranium-238 to another fissile element, namely, plutonium-239. Moreover, the PHWR does not require a large size pressure vessel.

Next we wanted that the technology development has to be totally indigenous. This includes both the reactor technology and the fuel cycle technology which includes mining of uranium ore, its processing, fabrication of fuel, utilization in the reactor, reprocessing of spent fuel and finally immobilization of high level nuclear waste. Considering the fact that our known uranium reserves are modest but the thorium reserves are very large, the three-stage nuclear power program has been envisaged.

In the first stage, the natural uranium is fed into the pressurized heavy water reactors for generating electrical power and for producing fissile plutonium-239 from the fertile uranium-238 in the reactor. And you can see that with our resources of uranium, we have something like 300 Gigawatt electrical-year total energy potential that will come from indigenous uranium reserves. Plutonium produced in the first stage is going to feed the plutonium-fuelled fast breeder reactors in the second stage of nuclear power programme. With conversion of uranium 238 into plutonium, the energy potential can be multiplied by a factor of

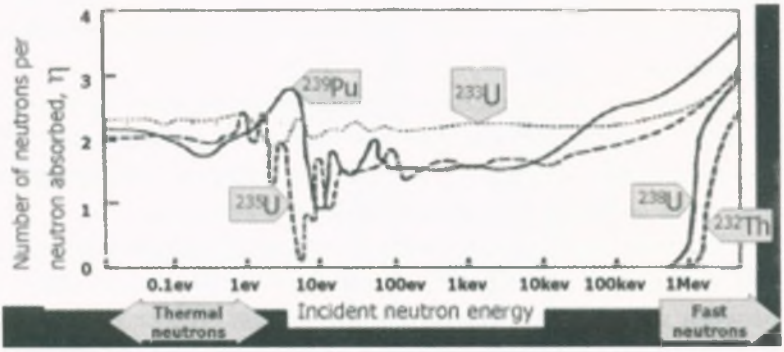


Three stage Indian Nuclear Power Programme hundred or so. Moreover, in the second stage with introduction of fast breeder reactors with high breeding ratios the installed capacity can be raised rapidly.

Thorium is yet another fertile material which once converted to fissile uranium 233, can fuel our reactors in the third stage of the programme. Once we come to that stage, we can sustain a high level of power production for several centuries.

This three-stage program requires a kind of successive growth, and it is simply not possible to jump or bypass any of the in between steps. Let me explain the role of fast breeder reactors in the three-stage programme. An important reactor physics parameter called h is the average number of neutrons liberated in a single nuclear fission. The variation of h with energy of the neutron is different for the three fissionable nuclei: uranium-235, plutonium-239 and uranium-233. For plutonium-239, it increases to a value close to 3 at neutron energy exceeding 1 MeV. This number is very important. While we need one neutron to continue the chain reaction, the second neutron can be utilized for converting one more fertile nuclide to a fissile nuclide for producing fresh fuel for fuelling the same reactor. And h being more than two, opens up the possibility of breeding that is generation of fuel which can support a second reactor. This is the advantage of using plutonium in fast neutron spectrum of fast reactors. Excess neutrons thus produced can be utilized to convert thorium into uranium-233.

The three stage programme invariably requires operation of the closed fuel cycle. This concept has found international acceptance only recently. Till last year, major countries in the world were not adopting the closed fuel cycle because it involves handling and using plutonium. The recent change has come about as it is being recognised that the closed fuel cycle is also essential for the long term management of nuclear waste. Normally, the lifetime of radioactive waste burden is over 10,000 years and that can be reduced to less than a few hundred years if one adopts the closed fuel cycle. This can be further reduced with the induction of

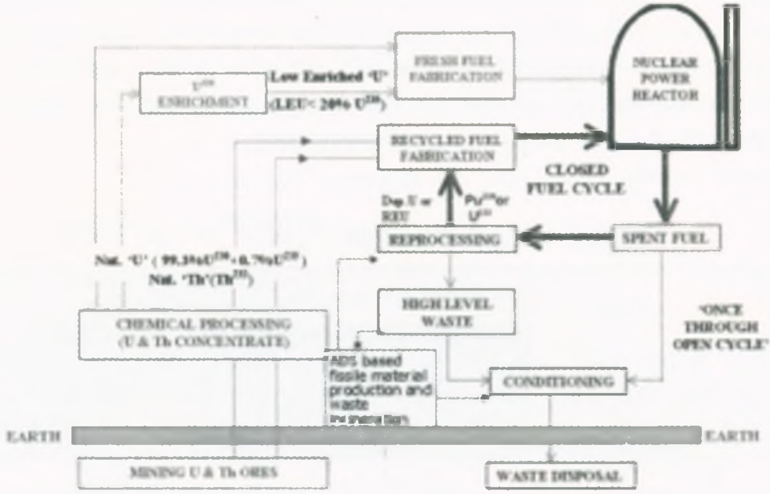


Number of neutrons produced per fission in ^{235}U, ^{233}U and ^{239}Pu

accelerator-driven systems where nuclear waste incineration is possible to a large extent.

What is this closed fuel cycle? Mixed uranium ore goes through several steps of chemical processing for making either natural uranium or enriched uranium fuel for feeding to nuclear reactors in once through fuel cycle. After burning a major part of the fissile nucleide U^{235}, the spent fuel is conditioned and dispersed in a long term disposal site. In contrast the spent fuel which contains Pu^{239}, is reprocessed for recovering this valuable fissile material which can be used very effectively in fast reactor. In contrast in the once through cycle one essentially takes out uranium ore from mother earth and dispose plutonium and many other higher actinides which have much higher radiotoxicity level and very long radioactive life essentially creating a radioactive mine.

Plutonium is best used in the fast breeder reactors, as is planned in our second stage of the program. Fast reactors also will convert thorium to fissionable uranium-233 which can be used in the third stage. In the closed cycle most of the higher level radioactive waste is incinerated in fast reactors and therefore the long lived waste burden is substantially reduced. The relatively small volume of radioactive waste is vitrified in the form of very stable glass, which can be stored in a deep geological repository with several protective barriers.

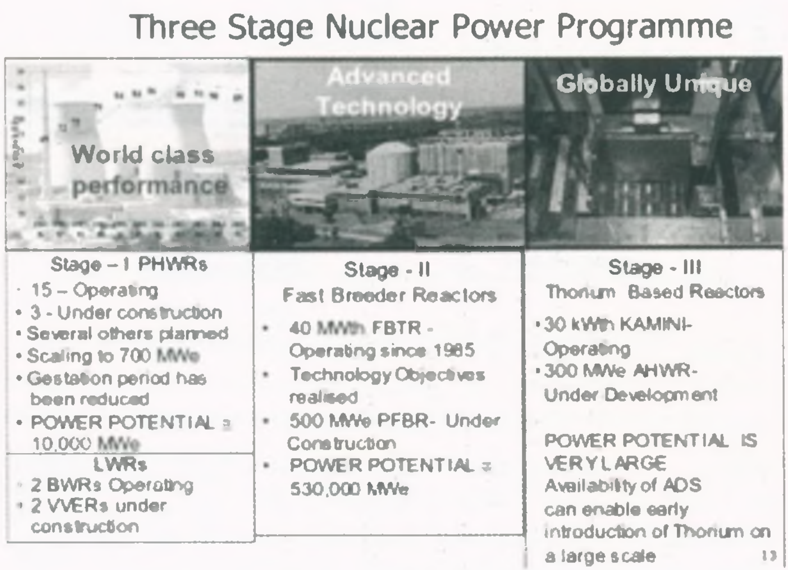


'Once-through Open Fuel cycle' and 'Closed fuel cycle'

3. CURRENT STATUS OF THE THREE STAGE PROGRAMME

Where are we in the three-stage program today? The PHWRs are operating using natural uranium as fuel and are generating electricity, and also producing plutonium. Presently, we have fifteen operating PHWRs and two boiling water reactors. We have three more PHWRs and two Pressurized Light Water Reactors under construction. The latter are the 1000 MWe reactors coming up at Kudankulam with Russian assistance. India has the largest number of reactors under construction today. Indian PHWRs have also registered record capacity utilization. On the basis of the experience we have gained with a 40 MWt fast breeder test reactor operating for the last 20 years. We are building a 500 MWe prototype fast breeder reactor (PFBR).

Already we have some experience with the Kamini reactor using uranium-233, separated from spent fuel containing thorium. But this is just a small (30 kWt) critical facility. We are now working on the design of a 300 MWe advanced heavy water reactor, which will be a technology demonstration reactor for thorium utilization and give us initial experience to handle thorium-related technologies. And then, we are going ahead with the development of a high-temperature reactor, which is under design. And finally, the accelerator-driven systems will lead us to sustainable energy production on a scale of several centuries.



Three Stage Nuclear Power Programme

The reactors operating today are all distributed across the country. Till recently, in India, nuclear energy has been cost comparative if they are located about 800 kilometres away from the coal pit. But the situation is changing very rapidly and nuclear power is becoming competitive to thermal power even in the vicinity of the coal pit.

I will just outline the proposed program of 20,000 MWe by 2020. The current installed capacity is 4,120 MWe. The three PHWRs under construction will take us to 4,780. Two reactors at Kudankulam will raise this capacity to 6,780. With the 500 MWe

PFBR we will reach 7,280 MWe. We are also planning to build another eight 700 MWe PHWRs and four fast breeder reactors of 500 MWe each. This is the projection of the growth of nuclear power till 2020 primarily through indigenous technology. There is a possibility of adding more nuclear power stations through import which essentially depends on the much talked about International Cooperation.

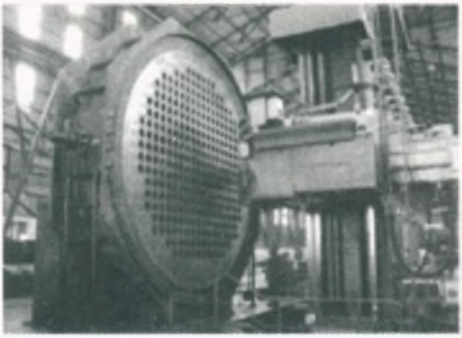
4. CHALLENGES IN NUCLEAR PROGRAMME

Now let me tell you the challenges we faced and how they were met. The much needed indigenous capability in fabrication of fuel, structural materials and mastering heavy water technology for PHWR programme has been achieved. Development of sophisticated equipment, computerized reactor control system, repair, refurbishment, life estimation and extension of reactor components, improvement in several safety features, reduction in the construction time have been accomplished.

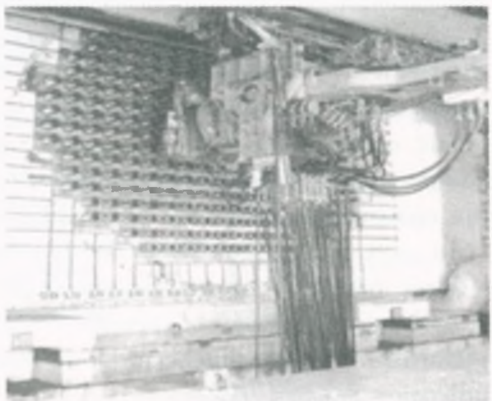
In each of the above items, we have had success and reached a level of maturity. It is finally reflected in the performance, which is always given in terms of capacity utilization. The Indian PHWR performance indeed touched a world record in 2002; the capacity utilization reached 91%.

The PHWR has a lattice array of pressure tubes, each of them providing a pressure boundary for the high temperature high pressure heavy water coolant to extract heat from the fuel bundles placed inside them. Heavy water is carried in to these coolant channels through a myriad of primary heat transport pipes. The fuelling machine has to engage with each of these pressure tubes for managing the fuel bundles. So one can imagine a huge reactor, where the distributed pressure boundaries are being penetrated every day. Mastering this extremely difficult technology by the Indian engineers has been a noteworthy achievement.

India is one of the very few countries of the world who have the indigenous capabilities for the entire fuel cycle. Manufacturing



PHWR END SHIELD



FUELING MACHINE

nuclear fuel and structural materials meeting the stringent specifications has become fully standardized and the performance of these components are upto the international benchmark.

Where do we stand in regard to fast reactors today? We now have good experience of operating the fast breeder test reactor. It operates at around 550°C using liquid sodium as coolant. Sodium and that too in the liquid state, is a very reactive metal. Use of sodium as the primary coolant of the fast reactor offers a number of technological challenges. We can proudly say that in these 20 years, we did not have even a single failure of the fuel clad in this sodium environment.

We have been using a mixture of uranium carbide and plutonium carbide as the fuel, for the first time in the world. Such a fuel is being used which has generated over 150,000 MWd of energy per tonne. This is indeed a very remarkable success. The discharged fuel has also been reprocessed to recover plutonium which will not only support the fuel for its own, but also generate enough fuel for starting more reactors.

Breeding new fissile material is possible only if fuel is successfully reprocessed. We now have adequate plutonium inventory to make 500 MWe fast breeder reactors. The construction of first 500 MWe fast breeder reactor is already started in 2004, and we expect it to be operational by 2010.

5. GROWTH OF NUCLEAR POWER

The initial growth of our nuclear power is through PHWRs. Next will be fast reactors with metallic fuel. I just mentioned to you about the breeding ratio or the doubling time; i.e., how quickly one reactor can generate fuel for a second reactor. The doubling time for present oxide fuelled fast reactors is rather long. So improving breeding ratio using metallic fuel is one of our important agenda. This will greatly reduce the doubling time to about 20 years or so. That will lead to a faster capacity of growth and then it will also be possible to increase the unit capacity to 1000 MWe.

6. INTERNATIONAL COOPERATION

There have been a lot of discussion and newspaper reports on international cooperation in nuclear energy. What are the advantages? First, in India, we will have a faster build up of power generation capacity in the next two to three decades. As I mentioned to you, we will not need any external fuel supply when we use the thorium reactors. But it will take a few decades from now and it is not possible for anybody to reduce this time.

The second advantage is that we can induct large-sized power plants – 1500 MWe plus – and co-locate four or six of them in a place. So that will immediately solve the present power crisis. We can also indigenize the light water reactor technology and development. This will essentially require reactor pressure vessel manufacture and uranium enrichment on a commercial scale. On both these fronts, we had success on an experimental scale. It is possible to go for full-scale industrial development as soon as we go for the pressurised water reactor (PWR) technology. There is an important advantage to have a mix of PWRs and PHWRs. The spent fuel from PWRs can be fed to PHWRs without reprocessing. So, very interesting fuel cycle possibilities will emerge.

Under international cooperation, natural uranium in the form of yellow cake can be imported, and used to run Indian PHWRs. Then Indian industry can support capacity growth of 1000-2000 MWe per year and the PHWR programme can be expanded beyond 10000 MWe.

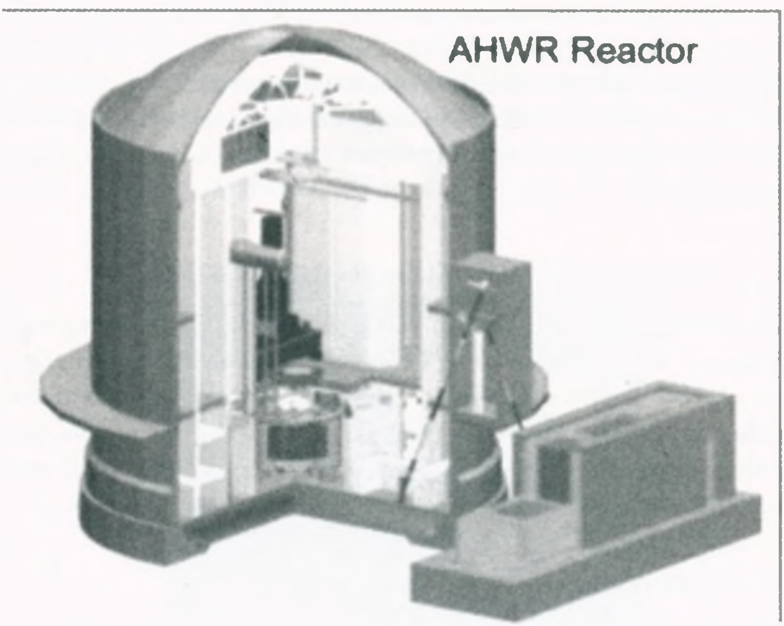
But what are the advantages to the world? First of all our experience of the PHWR technology can be shared with any country entering into the nuclear energy program. Our 200-500 MWe sized plants will be most suitable for such countries. We can share experience in operation and replacement of components, coolant channels, feeder pipes, etc. We have done these at lower man-rem expenditure, that is, the quantum of radiation exposure to operating staff engaged in such operation On this count our record is the best in the world. We can export structural materials and heavy water. We can also play a leading role in disseminating fast reactor and thorium fuelled reactor technology. Another important point is that with the price of fossil fuels in international market will be decided by the growing Indian energy demand. We can also save significant amount of CO2 burden by reducing dependence on fossil fuels.

7. INNOVATIVE REACTOR DESIGNS

Regarding innovative reactors, we are planning to jump into the third stage of the program, which is based on thorium utilization.

We have made a design of an advanced heavy water reactor (AHWR). This is a heavy water moderated and light water cooled reactor. The power output will be 300 MWe and a major part of that will come from thorium. An important feature of AHWR is that it will have a passive cooling system based on natural circulation driven by a thermo-siphon.

This technology which has been proven experimentally will be one of the inherent safety features. The design life of the reactor is about hundred years which will improve the economics considerably. The design concept of this reactor has been included as one of the innovative concepts in the IAEA forum.



AHWR Reactor

8. HYDROGEN ECONOMY & HIGH TEMPERATURE REACTORS

Next important development is in the high temperature reactor technology. Water cooled nuclear reactors work at about 300° Celsius. If the coolant temperature is raised to ~ 950-1000 degrees, nuclear power can be used in the hydrogen economy. Hydrogen is one of the best carriers of energy and is a substitute for fluid fuels. The sulphur-iodine thermo-chemical process can break up water molecules into hydrogen and oxygen. Hydrogen production at about 80,000 m^3 per hour is possible with a 600 MWt high temperature reactor from which electricity is also produced. Low grade heat from the same system can be used for desalinisation to produce potable water. In existing reactors, in the off-peak hours, we can do electrolysis – steam electrolysis or water electrolysis – leading to hydrogen production. So this is how nuclear energy will be linked up with the hydrogen economy.

Towards developing the high temperature reactor technology, we have taken up the design and development of Compact High Temperature Reactor (CHTR). This 100 KWth, 1000°C, three layer coated TRISO fuelled reactor will serve as a technology demonstrator for HTRs. The engineering system development for HTR having 600 MWth, 1000°C, TRISO fuel is also being pursued.

9. ACCELERATOR DRIVEN SUB-CRITICAL SYSTEM

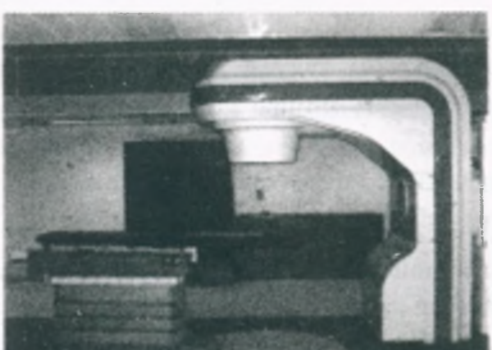
The accelerator-driven system will be inducted into our program, maybe a few decades later. In addition to producing energy, converting fertile material to fissile, it will also be useful for reducing the burden of waste in the long term. Eventually, the fusion-based reactors will come in to force, and they will also support waste incineration as well as electricity production.

10. APPLICATIONS IN HEALTH CARE

Non-power applications of radiation and isotope technologies pertain directly to healthcare, nuclear agriculture and food preservation, industrial applications and urban and rural waste management.

We use gamma radiation and electron radiation in radiation technologies. In addition to food preservation, these are used for sterilization of medical products, treatment of municipal waste, and breeding of new seeds via mutation. Each of these applications is well developed in our program. In healthcare, the radioisotopes Iodine-131, Iodine-125 or Technetium-99 are used for diagnostics. Radiation therapy is done with Cobalt-60, Caesium-137, Iridium-192 and Phosphorus-32. Sterilization via radiation is done often with Cobalt-60. We have also built tele-therapy machines for radiation treatment. One of our indigenously developed machines has been supplied to ACTREC in Navi Mumbai. This machine costs just half that of the imported one, while matching with all the international specifications. The Tata Memorial Centre at Mumbai is in the network of 19 regional cancer centres spread all over India.

We supply isotopes to over 500 RIA labs and about a hundred nuclear medicine centres all over the country. Majority of the hygiene products that we use are actually being sterilized by radiation at the ISOMED in Mumbai for over 30 years. Another



BHABHATRON: The Indigenous Cobalt-60 Teletherapy Unit five plants are working in the country for medical sterilization. The advantage of this programme is that the sterilization is done after packing thereby avoiding any infection later.

The use of radiation processed hydrogel is very effective for dressing burn wounds because it allows wounds to breathe easily while keeping them completely sterilized. Radiation processed hydrogel is already a commercial product.

11. LINKAGE WITH AGRICULTURE

Using mutation by radiation and by cross-breeding we have developed 26 approved seeds which are already put to farmers' use. We are particularly successful in oilseeds and pulses. Their yield, quality and stress, both biotic and abiotic have been improved considerably. The new groundnut seeds are large in size and belong to confectionery variety. The Trombay-Akola urid, TAU, is so popular that this variety covers about 95% of the total urid cultivated in Maharashtra, and 40 % in the country.

Several radiation processing plants are now coming up in the private sector. Any mutation that occurs in nature is also done by cosmic radiation. We simply accelerate the process through artificial radiation. There were some misgivings initially that if something is done by radiation it will induce radioactivity. However, electromagnetic radiation cannot induce any radioactivity in food substances. The success in spreading the use of radiation mutated seeds is due to our linkages with agriculture universities, seed corporations, Krishi Vigyan Kendras, non-governmental organizations and also through progressive farmers.

12. FOOD IRRADIATION

The shelf life of onions and potatoes is limited due to sprouting. This can be inhibited by irradiation. Both gamma radiation and electron radiation can be used because we need to treat only the surface as sprouting is a surface process. In case of rice, pulse or rawa, insect disinfection is needed. In the recent past, exporting

KRUSHAK irradiator at Lasalgaon, Near Nashik

mangoes has become possible after the quarantine treatment we give via irradiation. Microbial decontamination is essential in spices before export. We have a 30 tonne per day plant operating in Navi Mumbai since 2000. The KRUSHAK irradiator at Lasalgaon near Nashik has a capacity of processing 10 tonnes onions/potatoes per hour.

13. INDUSTRIAL APPLICATIONS

Radio-isotopes have several applications in industrial radiography, industrial tomography, nucleonic gauging systems, radiotracer applications, and cross-linking of polymers. I will illustrate a few of them.

In large-scale chemical plants, any internals are visualized using gamma scanning. A gamma source and a detector are moved along the height of tall columns of chemical plants. Internals of column, flow, blockage, etc. can be easily visualized by ¡-ray scanning.

A major use of electron beam irradiation is in cross-linking of the polymer insulation of high capacity electric cables. Railways and also some Naval units are making use of this technique.

Other uses of radiation are in shape memory applications in polymeric material and colouration of diamonds. By creating colour centres, ordinary diamond can be changed to coloured diamond. This is an extremely profitable operation. We are building a 10 MeV Radio Frequency Linac for use in electron irradiation – which will be used for both food products and industrial items.

14. DESALINATION

Desalination is an important component of our work. We are trying different techniques for desalination; namely, reverse osmosis, multi-stage flash evaporation, low-temperature evaporation and hybrid systems.

At Kalpakkam we are building a hybrid nuclear desalination plant employing the multi-stage flash evaporation and the reverse osmosis technique. The low pressure steam from a power plant can be directly used for multi-stage flash (MSF) evaporation. The product of the MSF stream is complemented by another stream based on reverse osmosis (RO) desalination. Generally RO water degrades with extended period of operation of the membrane used. The MSF water being very pure, the hybrid system will be able to maintain the quality of potable water for an extended period. The estimated cost of the desalinated water from Kalpakkam plant is about 12 paise/litre. In Lakshadweep we have provided the design of a desalination plant which makes use of the temperature difference between the surface and the deep interior in the sea. This difference in temperature is enough to run the plant. Our RO based desalination plants are in use in several villages in Rajasthan and Andhra Pradesh. In coastal areas, where scarcity of potable water arises in some occasions, barge-mounted desalination plants can be very effective. A demonstration plant of this type has recently been fabricated.

We have also developed a technology for domestic water purifier. Twelve companies are currently selling these filters using our technology.

15. MANAGEMENT OF MUNICIPAL WASTE

Gamma irradiation is also used for management of municipal waste. We have set up a plant in Baroda which takes in the sewage waste and makes it totally pathogen-free after radiation treatment. This waste, which is otherwise difficult to handle, becomes good saleable manure. The total count of harmful bacterial drops down significantly which enables substantial increase in the count of rhizobium introduced in the sludge. With increased rhizobium the efficacy of the manure for nitrogen fixing gets enhanced. This manure is being marketed through the Krishi Vigyan Kendra in Vadodara.

For recycling urban and rural waste, we have developed a facility to treat kitchen waste and convert it into methane in a biodigester. Methane can be fed back to the kitchen as a fuel or can be converted to electricity. This process has been quite useful in hospitals. Already seven plants are operating and many more are under construction. It is a cheap way of converting waste into energy.

16. SPIN-OFF TECHNOLOGIES

In the course of developing nuclear technology, a wide variety of spin-offs have also been developed. To cite few examples, I must mention the successful development of a range of electron beam melting, welding and processing of equipment, pipe inspection gauges for assessing the health of cross country oil pipelines and several scientific equipment such as mass spectrometers, x-ray defractometer and radiotelescopes.

17. CONCLUDING REMARKS

I have outlined the overall programme of our research centre. This year, we are celebrating the 50 years of BARC. Pandit Nehru inaugurated the then Atomic Energy Establishment Trombay (AEET) on 21st January, 1957. Many doubts were then raised as to how a developing country such as India will progress along the path of nuclear technology. India being a developing country can grow in the path of highly sophisticated nuclear technology. Today, when we have the complete indigenous capability of building nuclear reactors of 540 MWe capacity, acquired the mastery over the complete nuclear fuel cycle and demonstrated the wide ranging applications of radiation and isotope technology in industry, health care and agriculture, we can definitely claim that the dreams of Nehru and Bhabha have been fulfilled.

The success of nuclear energy programme has received international acclaim. The possibility of collaboration between India and other advanced countries in nuclear technology is opening up. I would like to conclude my presentation by describing the present scene by a cartoon with a legend quoting Mahatma Gandhi says "I do not want my house to be walled in on all sides and my windows to be stuffed. I want the cultures of all lands to be blown about my house as freely as possible. But I refuse to be blown off my feet by any".

Winds of Change

I do not want my house to be walled in on all sides and my windows to be stuffed. I want the cultures of all the lands to be blown about my house as freely as possible. But I refuse to be blown off my feet by any.

- Mahatma Gandhi

QUESTION ANSWER SESSION

Dr M R Srinivasan: Thank you for a very comprehensive coverage of the developments in the field of nuclear energy. I believe we can take a few questions?

Questioner: You have used your applications for pipeline inspection in steel pipes. Can it be used for concrete pipes or earthen pipes like sewer line inspections? Because there are a lot of leakages in the sewer lines in most of the cities, including Delhi, Bangalore and that is polluting the ground. Can we inspect such pipes through your system?

Dr Banerjee: It will be very difficult. This is due to two reasons. Leakage is detected in steel pipeline using the principle of magnetic flux leakage. Therefore, it will not be possible to use this technique for concrete pipes. In case steel liners are used with concrete pipes, discontinuities in steel liners can be detected, in principle.

Questioner: Can the polluted lakes also be recycled? Like in Bangalore, for example, we have about hundred lakes, some of them are very polluted.

Dr Banerjee: What is needed will be more like a desalination type process from brackish water. By reverse osmosis, one can purify that water for making it potable.

Questioner: Then we will have rain water and the lakes can supply drinking water to Bangalore.

Dr Banerjee: I think you are asking a slightly different question. That is called the rain-water harvesting program in which rain water is effectively collected and stored in large ponds or underground aquifers.

Questioner: I mean a recycling method like...

Dr Banerjee: For recycling, one can use reverse osmosis as a very effective tool of changing the quality of water and making it potable. And for that, one of the major inputs is the suitable membrane. We have a very strong program on the membrane development and the membranes developed in BARC are working quite satisfactorily.

Questioner: About the radioactive application in the food and agriculture sector, doesn't it have any harmful effect on human health? Will agricultural products like onion and potato which have been exposed to radiation be harmful to human health?

Dr Banerjee: Any electro-magnetic radiation cannot transmute a substance to a substance which is radioactive. Basic principles of physics will straightaway exclude the possibility of something becoming radioactive by gamma rays. This is an unfounded fear in the minds of people and it is only through education that we can remove this kind of apprehension. I can say this with hundred per cent assurance that something irradiated by gamma radiation will not become radioactive. So there is no problem.

Applications of Space Technology

K KASTURIRANGAN

The Indian space programme is recognised today as one of the most successful one in the world in the mastering of several technologies against several odds, but more importantly, in utilising these technologies for the direct benefits of the society. I am happy to present before you, the emphasis given to applications of space technology that has important societal implications.

Let me talk about some basic issues: how do we institutionalise and make society accept new science and technology outcomes so that it feeds into societal development? The Indian space programme perhaps occupies one of the very pre-eminent positions in the larger context of societal development in the country. It is not only in the context of our country's development but also as an example of what a developing country could do to absorb the high-end of technology.

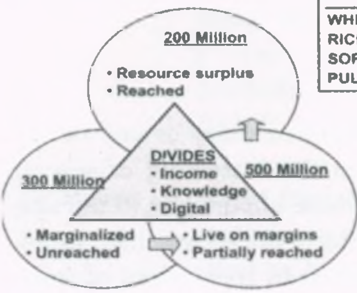
ASSETS AND VULNERABILITY

It is useful to know some statistics related to India, where space becomes relevant. It is not a question of bringing all the dimensions of the problems that one is familiar with when we talk of this country but the question of the population and of resource surplus — the upper 200 million population which can afford and the 500 million in between which live on the margins but have some ability but not to the level of the upper 200 million. There is also the marginalized, 'unreached' population of about 300 million which is well below the upper two levels in terms of income, quality of life, knowledge, digital access and so on.

India: A Snapshot

World's most pluralistic society (race,caste,religion,language...)

Population : 1100 Million
(700 Million in Villages)



CROP	AREA (Mha)	PRODUCTION (MT)	PRODUCTIVITY (T)
WHEAT	25 (3)	69 (3)	2.5 (32)
RICE	42 (1)	82 (2)	2.8 (51)
SORGHUM	11 (1)	10.5 (2)	0.9 (51)
PULSES	25 (1)	14.8 (1)	0.6 (118)

Source: Dr MS Swaminathan

Food Security	Now	2007*
Food Production	212 Mt	230 Mt
Per Capita	180.2 kg/yr	182.5 kg/yr
Population	1100 M	1135 M

* [illegible]

- Widening Divides
- Regional Disparity..

MAJOR CHALLENGES

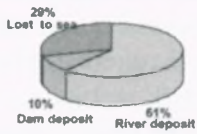
Poverty Alleviation, Food Security, Sustainable Development

Agriculture is a major occupation of a majority of Indian population and it contributes to the GNP in a very big way. Even though we rank third in the world in wheat production, the productivity in tonne per hectare is very low and we are ranked 32. Obviously there is a problem of productivity. Similar is the case in rice production; we are the first in terms of the cultivated area but again in terms of productivity, we have serious problem. Sorghum and pulses are some other examples. The major challenges as evident from these statistics are poverty alleviation, food security and sustainable development.

A similar situation exists in regard to our land resource. The geographical area is 329 million hectares. We have a net sown area which is about 143 million hectares, both irrigated and rain-fed. We have a forest cover of 64 million hectares — both closed forest and the open forest – which has fairly large bio-diversity. But it is fast degrading and depleting. If we look at the water resources of the country, we have fairly good rainfall — about 400 million hectare metres precipitating over the Indian land mass. But the amount of water that is used is about 50 million hectare meters. Irrigation takes about 35 million hectare metres and other uses account for 15 million hectare meters. But what is important to

Land Resources: Depleting Base

India's Annual Soil Loss 5334 Mt



Geographical area: 329 Mha
Net Sown Area: 143 Mha (109 Mha under Rainfed)
Forest Cover: 64 Mha
Biodiversity Richness

Natural Disasters

- 5700 Km Long Coastline -Cyclone-prone
- 40 Mha - Flood-prone
- 68% of Net Sown Area (116 Districts) – Drought-prone
- 55% Total Area - Seismic Zones III - V
- Sub-Himalayan/ Western Ghats -Landslide-prone

Water Resources: Scarcity in Abundance

Total Usage
51 out of 400 Mham water annually

Irrigation
35 Mham

75 % Rainfall in less than 100 days (SW monsoon)

Other Uses
16 Mham

Rainfall zone (mm)	Geogr. Area (M ha)	Water avail. (M ha m)
100-500	52.07	15.62
750-1000	65 86	57.63
1000-2500	137.24	205.86
>2500	32.57	95.86

note is the high temporal and spatial variability. Even though we have plenty of water, the question of management of water in the various sectors of national endeavour is the need of the hour.

We have a coastline of 5,700 kilometres a significant length of which is cyclone-prone. About 40 million hectares of our land is flood-prone; 68 percent of the net sown area is drought-prone; about 116 districts or 55% of the total area comes under seismic zones lying in the third, fourth and fifth categories and the sub-Himalayan and the Western Ghats are landslide-prone. Thus, we have many problems related to natural disasters.

We talk about major challenges in monitoring and managing natural resources as well as the infrastructure built-up. Qualitatively these issues have not changed very much since independence; but quantitatively, the numbers are very different. There are also questions of education, poverty, healthcare and so on.

CHALLENGES FOR THE SPACE PROGRAMME

Could a new technology like space address some of the above problems in an effective manner — in a manner that the conventional systems cannot? The Indian space programme went ahead in a manner that was unusual in trying to answer these questions. First, it was necessary to test the space systems for various applications. This was done through some historic experiments, the Satellite Instructional Television Experiment and the LANDSAT data acquisition for remote sensing applications. The Satellite Instructional Television Experiment was primarily to prove the efficacy of a satellite-based system for distance education, developmental communications, mainly to convey messages related to health care, agricultural practices, environment and the like, specifically to the population in the rural areas, where there is a big knowledge divide. Imparting knowledge to the rural population was therefore one of the central theme that was addressed in this experiment. About 2,400 villages were covered and 2,00,000 participants were involved. It was the largest sociological experiments conducted anywhere in the world. It paved the way for developing the concept for the Indian National Satellite System, the INSAT.

The experiment using LANDSAT, primarily addressed questions like: can we get timely, precise and accurate information about our natural resources? The LANDSAT provided vital images over the country where we could look at the wheat fields, forest area, geological areas, environmental aspects, the coastal regions, and so on. For the first time, the Indian Space Research Organisation, along with the user community, evaluated satellite-based imaging capability for addressing some of the issues relevant to our country.

INSAT-4B

Another area we looked at was telecommunications. An interesting experiment was conducted using the Anglo-French satellite, Symphonie, to integrate the conventional ground systems in telecommunication and see the efficacy of a satellite-based system when it is integrated with the conventional ground system. We must note the status of telephone connections in those years. There was practically nothing in the northeast region. The downrange islands were not connected and in the hilly terrains, forested areas, there was a serious problem of communication. Except in the urban areas, there was hardly anything that could be called communication in the country. This is the background in which the satellite system evaluation was done. The user community was brought in and an awareness of the capability of the satellite system was created. This ultimately paved the way for first establishing a certain type of operational system.

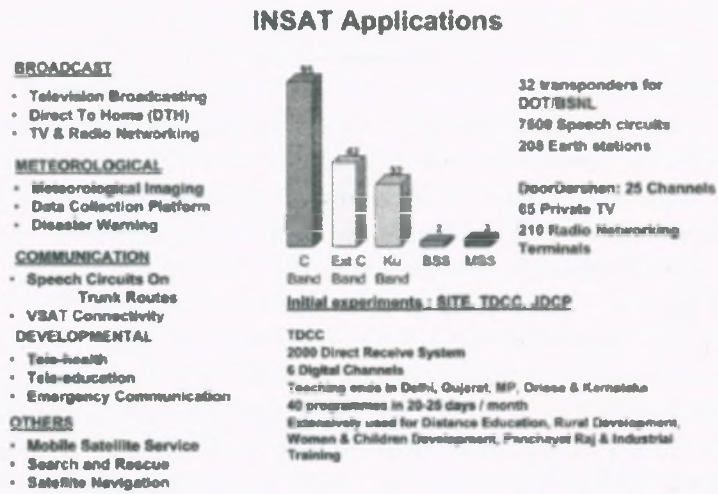
While establishing the operational systems, which we today call the Indian Space Programme, we had to translate all that experience, not only in terms of technology, but also, in terms of the application potential and in terms of working with the users, which are very critical aspects. How to absorb it within the societal system? This is where I think we should pay our tributes to Professor Satish Dhawan for the critical role he played in trying to institutionalize the capabilities by creating systems within the country. He introduced what is called the INSAT Coordination Committee (ICC) to deal with the communication satellite programme and the National Natural Resource Management System (NNRMS) to deal with the natural resources. The Planning Commission is responsible for the resources management in the country and, therefore, under the aegis of the Planning Commission, Prof Dhawan created a body to address the question of timely information about the natural resources and they became the focal point for the remote sensing system, that followed the LANDSAT experiments. And ultimately, of course, for Space Science, which is really more on the enrichment of knowledge, he created an Advisory Committee on Space Sciences. These three bodies which formally brought in an institutionalization not only to create an awareness but a demand for Space systems. Once this was established and a pattern was set, there was no question of searching for users of a satellite once it is put into orbit. We worked with the users. The users specified their requirements which were translated into missions and then those missions are the ones that ultimately became an integral component of India's Space Programme Planning. And, of course, the Space Commission, which is the topmost body, was representative of all these needs at the national level.

What has happened in the last forty years or so since the first rockets were fired from the Thumba Equatorial Rocket Launching Station, a modest effort in terms of scientific experiments? Something like forty spacecrafts have been put into orbit by India. Twenty of these were through the launch vehicles that were launched from within the territory, both through PSLV and GSLV and earlier with the smaller vehicles, the SLV-3 and ASLV. And, of course, you have a whole series of satellites that have been built with successive improvement in the capabilities and in tune with the increasing demands from the user community. We have a system of communication satellites at geo-synchronous altitudes and remote sensing satellites with varying resolutions and capabilities, which were put into polar orbits In the process, we have also ensured that there is self-reliance in the programme so that we are not affected by the vicissitudes of geopolitical changes. Two of the launch vehicles were developed to ensure that we have a sustainable activity in putting these classes of satellites into orbit — PSLV, which is compatible with the needs of putting into polar orbits the remote sensing satellites and the GSLV, which can put the communication satellites. What we today call the INSAT system is a multipurpose satellite system. The capability towards putting these classes of satellites was also developed. Today it is at the range of 2,200 - 2,300 kilogram, and moving towards 4 tonne in the next three years. Until then, wherever you have a heavier satellite, we have to launch it with outside support, which could be only one or two now, because we are closing the gaps with respect to the capability in each for the communication satellite and the capability for launching similar satellites from our own launch pads with our own launch vehicles.

COMMUNICATION SATELLITES

What is important to note about the communication satellites? In this I dwell a little bit on the technologies we have developed. These are all three-axis stabilized, ability to look at the ground steadily from Space. These are located at 36,000 kilometre above the Earth and consistent with modern trends, they have typically lifetimes of between ten years and twelve years. The systems which are sufficiently qualified in terms of their reliability and the components that are used have the necessary requirements. There are several demanding technologies that are implicit in a life of ten years to twelve years in these classes of satellites. They are currently operational and are controlled from the Master Control Facility located in Hassan, about three hours' drive from Bangalore. A number of user agencies have set up their own ground stations, right from a large ground station to Very Small Aperture Terminals (VSAT). Today they all form the basic ground infrastructure that services the INSAT kind of satellite systems. Even though a typical satellite may cost $ 200 million ultimately for establishing it, when it comes to using its full capability, you have to make three times as much in investment on the ground. So you can imagine the investment that has gone in ground station infrastructure in this country, thanks to the efforts of the user agencies, the Department of Telcommunication earlier, the Information and Broadcasting and currently, of course, many private operators who use these systems.

As I said earlier, the first experiment that was done, SITE, was primarily to make sure that we have an outreach from any point in the country to any other point, a point-to-point communication, point-to-multipoint communication or multipoint-to-multipoint communications and so on. But later on, it quickly transitioned also into the entertainment area, so you have television broadcasting today, which is substantially met by the INSAT system for television broadcasting, and TV and radio networking. I should say that it has an outreach today, which is more than 90% of the population and it covers more than 65%



of the country's geographical area. So that is the kind of outreach that the INSAT system has today.

Today, Doordarshan operates 25 of the channels, the national channels, the Regional channels, the Metro channels, etc. there are 65 private television channels, 210 All India Radio networking and so on. These ground systems have all been invested by the user agencies in using this system. You can see the level to which the INSAT system is currently used in the area of broadcasting.

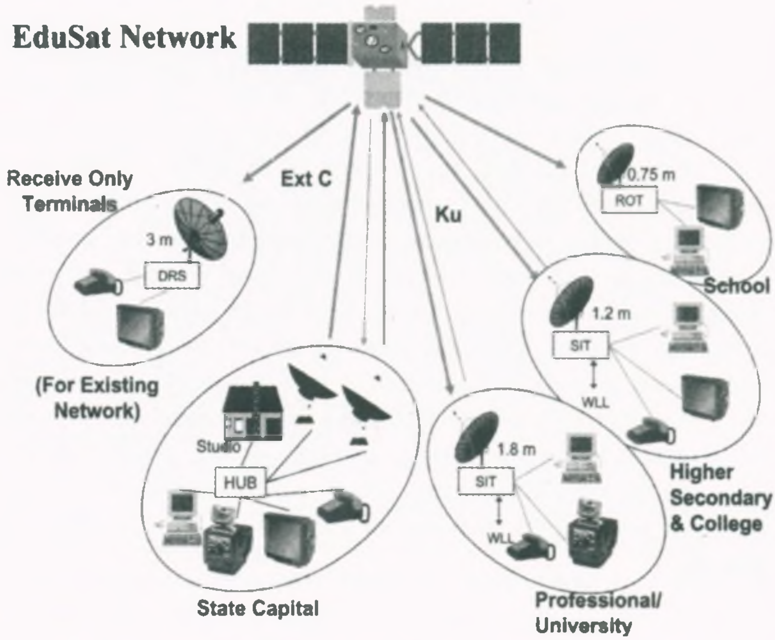
The second important area, is the meteorological system. We have the Very High Resolution Radiometer, which takes pictures of this part of the world. These imageries are available every half an hour and you can see the dynamic motions of the clouds. These data are obviously factored into meteorological predictions. We have a meteorological system which images both in the thermal domain of the electromagnetic spectrum as well as in the visible domain. The thermal band helps look at the radiation characteristics of the outgoing and long wavelength radiation and so on. And then we have data collection platforms which can collect the environmental data of interest in different locations in the country, uplink the same to the satellite and direct them to a central point. We can access data from all over the country, data of environmental interest, meteorological interest like the temperature, winds and so on. They are all collected, transmitted and ultimately received at specified locations for use in modelling.

On the communication side, the important things are the speech circuits, the Very Small Aperture Terminal, etc. We see the importance of this in areas like telemedicine and tele-education. More recently, there has been the introduction of the mobile satellite service, which will enable you to carry a suitcase-sized system with which you can connect through the satellite to different locations, particularly used for coastal surveillance and many other applications. And what is also significant is that many of the areas of work which we started with SITE and STEP, got further fillip in terms of developmental communication, like those related to agricultural practices, environmental preservation, watershed development and so on. But what is important is that TDCC, Training and Development Communication Channel, is also used for the training of the rural folk and ultimately we have the ability to dialogue with the rural folk with respect to the questions they may have and experts talk to them from the urban areas. These are what are called interactive communication channels that have been established. Several states in the country are today using this concept in reaching their own people in their respective states like in Delhi, Gujarat, Karnataka, Orissa and M.P. They produce programmes of relevance to local development, which are beamed almost 20 to 25 days in a month. One can see the extensive utilization of these kinds of systems for training and developmental communications.

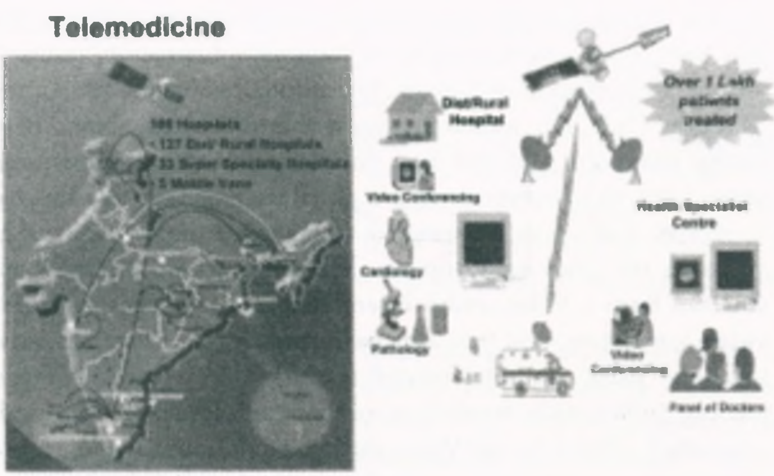
We can see the type of allocation of transponders in terms of the frequency bands in which they operate. Initially, we had extensive use of C-band and extended C-band. But with the newer requirements in various applications of communication and broadcasting, particularly in broadcasting, we have gone to higher frequencies with better bandwidth and therefore better signal-to-noise ratio. They are also easier to coordinate in terms of the orbital slots from which these satellites trnsmit. We also have the broadcasting channels and mobile satellite systems.

Right from the inception of the INSAT, emphasis was laid on the use of satellite systems for education in the country. By the time you go from the primary, elementary education to secondary education, we have many dropouts. If we analyze the reasons we find that it is to the children's inability to pick up science, mathematics and even a language like English. We have the problem of inadequacy in imparting knowledge. There is also the problem of large number of teachers required and the need to upgrading their knowledge. Hence one has to find unique and innovative solutions. Here are some examples of the type of innovations that we have tried to do. First of all, the satellite system and suitable ground systems have to be built which will meet these kind of requirements. Secondly, most of these systems operate not necessarily in the urban areas. So you need to have the ground systems simple, operable, reliable and the ability to give out the message that it is supposed to give with the simplest human interface. And, of course, the satellite itself has to cater to locale-specific, language-specific, culture-specific programmes and therefore what is applicable in UP cannot be applicable in Tamil Nadu. One has to deal with satellite systems which can specifically beam the locale specific programmes, not necessarily interfering with each other. These issues were all factored in and finally we came out with the interesting concept of a satellite, where we brought in the experience of more than ten years in space-based education to develop what we call EDUSAT, which has multiple beams.

Multiple beams essentially mean that you are able to cater to the regional news with reference to their specificity. Then you will also have a national beam where you can broadcast most of the general programmes, both in Ku-band and extended C-band. We have to give continuity to the extended C-band primarily because, in the previous systems, this band was extensively used.



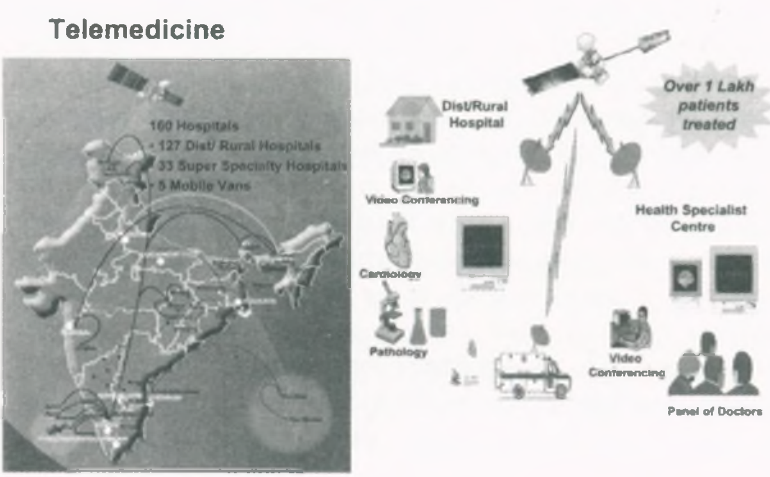
These are essentially high power beams. One can put ground systems which has less than half a meter diameter antenna, but you have a tremendous ability to transmit information, transmit lessons and transmit messages. These can be used both in the 'Receive Only' or interactive modes. In the former, you have virtual classrooms and you hear the speakers giving lectures from urban areas or wherever you have good teachers and you are able to receive it at several locations in distant areas of the country in video. In the latter case, you can also have a video interaction; you can have a video-audio interactive; you can have a video-video interactive; and you can have multimedia. They are used today for many purposes related to education, enrichment and training. In fact, more recently, as soon as the satellite was launched, a hundred colleges of the Viswesvaraiah Technical University were connected together and you had one single point, a classroom from which these lectures were delivered and there was an interactive mode in which the college students benefited out of some of the best professors who could talk to them through this virtual classroom concept. The Rajiv Gandhi Open University in Madhya Pradesh or Ambedkar University in Maharashtra are all coming into the picture and, of course, IGNOU has been one of the very important users of this kind of educational system. Today EDUSAT is fast catching up in terms of its ability to serve as an innovative tool for curriculum- based education, enrichment, training as well as development communication; but its capacity, I should say, is enormous. In fact, at one time we just computed that the kind of investment that we need to do justice to EDUSAT is not less than ten thousand crore rupees on the ground. This is being done in a phased manner. It is not possible to overnight fulfill the objectives of the EDUSAT in its totality because you need to still bring out a large segment of the ground system, including the relevant software, which could enable the EDUSAT's potential to be used in many of these areas of education and training.



Present Education Scenario in India: (a) 1027 Million Population; 350 million Illiterates. (b) 87 % Drop out by Std 12.

TELEMEDICINE

Next is the area of telemedicine. Today, 75 per cent of the best specialists are located in urban areas, about 23 per cent in the semi-urban areas and hardly two per cent in the rural areas. It is quite obvious that you don't have instantaneous specialized advice in areas like cardiology when someone gets a heart attack. It was in this context that we started experimenting. We started this with respect to a location that had a geographical problem, the Andaman and Nicobar islands. We introduced for the first time connectivity of the local hospital there with some of the specialized hospitals in Chennai like Apollo and Ramachandra Hospitals. And the interesting aspect is that we virtually transport four people per week from Andaman and Nicobar for specialized attention on the mainland. At least two of them, we found, need not have come if it was diagnosed properly at that place itself. And it is here, that we can see an improvement in terms of avoiding bringing patients unnecessarily here. You know, it costs the government exchequer more than two lakhs for transporting a patient from the islands to the mainland. So one can see the economics, the issues of urgency and the immediate attention that could be given even before a patient is transported, etc. Today we are able to



provide consultation because a specialist is able to give instantaneous or near-instantaneous advice as to what to do with the patient.

Today, 186 hospitals in the country are connected out of which 152 are district and rural hospitals and 34 super-speciality hospitals. In Karnataka, most of the rural hospitals are today connected. We have a large number of specialized doctors spending at least 15 to 20 per cent of their time. Narayana Hrudayalya has its own telemedicine system, which is use to provide service to patients who are as far away as West Bengal and Assam. The whole idea is to expand this to a large number of hospitals and thereby bring the health care systems within the reach of the rural and remote area population.

EARTH RESOURCES AND IMAGING SYSTEM

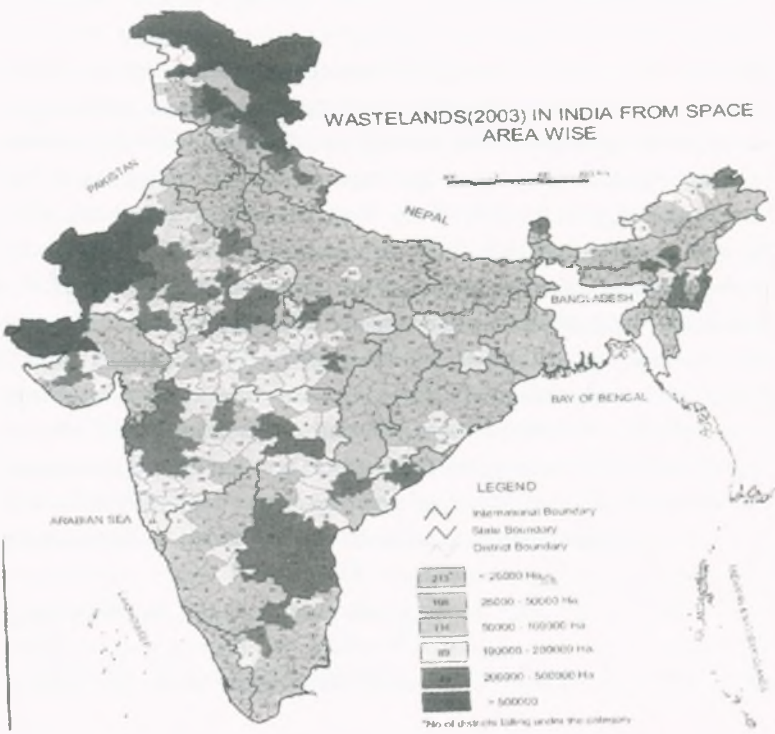
The second system that we evaluated was the use of the imaging system, the US LANDSAT system to look at the earth resources. Timely, precise and accurate information could be obtained and used in several applications. We built initially satellites with one kilometre spatial resolution, which was just an experimental satellite. We improved it, built satellites with 360 metre and 180 metre, which could be used both for land application and ocean application. We built systems which could provide even better applications like agriculture. And then we go into improved systems for agriculture and land use, land use patterns and even urban sprawl. More recently we have gone into the mapping domain, the first time any country in the world has gone into the mapping domain. This is what is called a CARTOSAT-2 where you have a one-metre resolution, which gives you probably some of the best imageries in terms of the details in respect of built-up structures. So what is interesting is that you have these satellites operating and India has the largest constellations of remote sensing satellites anywhere in the world and the best in the totality of capabilities. And then you have also the geo-stationary orbit satellites, which primarily carry, as I said earlier, the Very High Resolution Radiometers. These are used for taking optical imageries and thermal imageries of the cloud patterns, cloud movements and so on. These radiometers have typically four to five kilometers resolution or ten kilometers resolution and the more recently introduced Charge-Coupled Device camera have one-kilometre resolution. Particularly from the point of view of meteorological applications, these are the ones that are used for land and ocean applications. These complement of imageries enables us the permutation and commutation to address several types of applications that are pertinent in terms of their resource management.

The quick summary of the kind of applications that we have developed are very much connected with the user communities in the country like Department of Agriculture, Department of Environment, Water Resources, Department of Mines, Disaster Management which is now under the Home Ministry. And we have Land Resources, Weather System, DST and India Meteorological Department, Department of Ocean Development and the Planning Commission which periodically asks for information on agro-climatic zoning and so on. These are all user-oriented in terms of the type of applications to which these satellite imageries have been used. I will only give a few examples. In the case of agriculture, today we have developed an entire methodology of providing information related to three or four major crops. In fact, our ultimate goal is to go for fourteen major crops in the country with the ability to provide accurate prediction at least one month before the harvest with an accuracy of 95% (and a precision of 95%) as required by the Bureau of Economics and Statistics. Just to give an example, for the last four to five years, we have been working with Orissa and some of the other state governments to look at rice cultivation and look at the predictions we can make. We have been able to provide predictions one month before the harvest and they are well within the accuracy of predictions they were looking for in the rice production. In fact they have often used that in trying to get an early warning of the level to which rice is going to be produced. Similarly wheat is another area.

The importance of satellite systems comes in because primarily you are able to repetitively look at the same spot or the same region. And then you can look at the growth phenology and the leaf phenology. The growth phenology gives you much information about the initial growth. For example, in the case of wheat, you have an entire leaf phenology which gives you an indication of the type of productivity of wheat that one can expect and then you look at the agricultural, meteorological information and the historical information with regard to the soil and so on. You factor them and you have yield models that have been developed in using these information. With all these, today, we are able to give predictions for two or three major crops and the hope is that one should be able to establish the full capability for fourteen major crops using a satellite-based system. This is an important input we routinely provide today. In fact I should say that, last month, the Department of Agriculture took a major decision to establish Forecasting Agricultural output using Space Agro-meteorology and Land-based observations (FASAL). This is a major step in institutionalizing satellite imagery in crop production estimates.

The importance of forest and environmental monitoring is so critical that it has been decided a few years back that, every two years, the state of health of the forest as seen by satellite imagery shall be placed before Parliament. So the authentic information today is from space imagery and you have every year a kind of information, the level of closed forest, the level of open forest and even the ground density. This is an important area where the Ministry of Environment uses satellite imagery. They can track down forest fires, especially using the LANDSAT data. Biodiversity classification is another environmental assessment. In fact, today, for several court rulings including the Devanahalli airport the assessment as to whether there is enough resources in terms of water, whether the environment is good enough for an airport to come there with all the attendant international traffic, hotels and other things is sought.

We know that sixty-five million hectares in the country is what we today call 'wasteland'. India has a very unique classification for wasteland - about thirteen classifications. And these classifications are like the rocky areas, the hilly areas, the marshy areas, degraded forest, etc. If you are able to do a mapping, if you are able to do the classification, then out of that classification we can identify which are culturable areas that can be retrieved and which are not. If these maps can be generated up to the district level, then you have an exceptional information system which can also be updated with respect to retrieval and so on and also monitoring the retrieval process.



The year 2000 maps show 64 million hectares. It has been reduced to 56; there has been reclamation that has been going on over the last six to seven years. They have also found out that 35 million can be ultimately made suitable for cultivation so this has been separated out. This kind of maps can be produced every two years, and you can know dynamically how the land is being reclaimed, how it is being changed, and how it is degrading because of excessive water, excessive fertilizers, pesticides, and so on. We have the problem of land degradation and we did see the lowest productivity in terms of 1.7 tons per hectare to 2 tons per hectare on many occasions in India compared to for example, what used to be grown in Punjab, something like 6 tons per hectare. So we have the questions of how to reclaim the land, which area and what is to be done? We have an information system, which has the potential of providing some very crucial inputs.

The dominant advantage of space imagery is that we get a synoptic view from the space. When we have a synoptic view we are able to see large geological structures. When we see large geological structures like the faults, the lineaments and so on, they provide an idea of the underground water reservoir systems over the subterranean ducts through which the water flows. We can get this signature only if we look at the synoptic view. And this can be obtained only from the satellites. Out of this we can create hydrological information from the surface features of the land. Then we can also create 'a view' that add to the geological information, hydrological information, and put them into a geographical information system, GIS. Out of layers of information system which contains all these you can create a model of what is the probability for hitting water based on some *a priori* knowledge. And this kind of a method of creating hydro-geomorphological maps using satellite imagery and collateral information has become a very significant aspect of input for ground water exploration today. These maps also become extremely useful in identifying the locations for recharging. Therefore we have a sustainability which can be introduced in terms of drawing the water and finding out the locations where the recharging could be done and also from which exploitation could be done. This methodology has been applied by ISRO working closely with the Ministry of Water Resources and the State Water Resources Department. A large number of states have completed this effort and you see the success rate in drilling bore wells. In Gujarat, for example, it is 100% in Madhya Pradesh, it is 90 % and in Andhra 93% success rate. One can see the potential of this method and the economics of not having to drill two bore wells for getting success in one. It costs Rupees 25,000 or even Rs 50,000 to drill a bore well. If you can avoid drilling 20,000 bore wells to get 10,000 bore wells, then you know what it means in terms of economics.

The next is an application related to the potential fisheries zones. The fishes normally agglomerate when there is a little difference in temperature. There is also a phytoplankton distribution, which is the fodder for the fish. The satellite imageries are able to look at them. You can get the temperature of the sea by using certain type of radiometers. You can also look at the sea using ocean colour monitors, which are spectrometers with ability to look at the chlorophyll content on the ocean surface. So this kind of imageries is used to monitor the ocean colour and the temperature. By making a mix of these two parameters and identifying virtually the locations in which the fishes can be found we have been able to generate maps that are typically valid for three to four days. These maps can be flashed to the jetties through All India Radio, etc. The fishermen are now quite adept in taking this information. They have reported fish catches, which have increased by a factor of 2 to sometimes as much as 7 or 8. This has been a very interesting application for which the Department of Ocean Development now uses the space imageries and routinely provides forecast to fishermen along the coastal regions.

DISASTER MANAGEMENT SYSTEM

For Disaster Management System we use both imaging and communication capability of space systems. Between them, we bring in a synergy and thus create a host of applications, which are applicable to flocds, drought, damage assessment, etc. It has its usefulness not only in the area of preparedness but also in the area of disaster event. We can monitor it, identify the locations for the reaching relief and prepare rehabilitation plan using these maps. We are able to get these information from space imagery immediately after a disaster. We can have reconstruction and monitoring and we can also take up mitigation plans. There are areas like water run-off characteristics, which can be studied from the imagery and plan to build bunds and so on. There are many levels of disaster management and mitigation in which space communication as well as space imaging systems play a critical role. Drought maps are also produced and provided to various states with regard to what is likely to be that year's conditions with regard to the crop yield.

We can see the details of what are the potential hazard zones in which instability could be there and proneness for earthquake, landslides, etc. One can look into all these and make an assessment, which can be used both for rehabilitation as well as for mitigation. Particularly, one has to avoid built-up structures in the fault zones. These are the kind of inputs that could be obtained from Space imagery.

In the context of tsunami, space based emergency communication and telemedicine facility in Andaman and Nicobar were used because all the other modes of communication systems broke down. We could also have the assessment of the extent of damage. High-resolution aerial photography was used to complement or supplement space imageries. Finally we could also make a certain level of detailed damage assessment, which as I said earlier, could be used for rehabilitation and reconstruction.

All these -- watershed management, panchayat planning, drinking water availability, weather inputs, etc, can ultimately be translated into user-specific information, which are needed in the rural areas. One could get these information from different agencies, synergise them and reach it to the different villages depending on their specific needs via satellite. The farmers could even interact with expert knowledge centres outside the villages and seek advice like those related to movement of fertilizers, cost of fertilizers, available sources, livestock management and so on. They can optimize their efforts. They can have input on weather services, know about government schemes for societal benefits, etc. For example, when an order is issued by the government related to some welfare measure, the beneficiary even in a far-off location, can know about the same and inform others.

IMPACT OF SPACE APPLICATIONS

Where is our space programme leading to? I can quote about the most recent satellites launched, the high power satellite, which will bring in television Direct-to-Home and countrywide access to classrooms. The use of EDUSAT and similar systems which will be established in the future, depending on the experience of this first satellite, would be an important aspect of the space programme in terms of education and training, multimedia applications, the ability to reach several types of messages and information, fax, telex messages, education, e-knowledge and so on, to evolve a knowledge-based society. Telemedicine is another important area. Special planning of land and water resources is very important. Just like we a population census, we could take a five-year census of the land and water resources. In the current pace of development, one should see very drastic changes in the land use pattern. Obviously there is a need to update the land use pattern for optimal management and also manage water resources. Here is where the importance of a satellite-based imaging system comes into the picture.

Disaster Warning needs to be operationalised in several areas. We are now closely working with the Home Ministry and other agencies and also we have a Decision Support Centre established at National Remote Sensing Agency, Hyderabad. Village Resource

Centre - a very innovative idea on which ISRO is experimenting now, will become an important component for a knowledge-based society as one could reach critical information to the villages depending on their needs in the context of their own endeavours. And ultimately we have to have an improved weather service although ISRO is not a panacea for problems of prediction.

On the whole, what I would like to say is that the space programme is an example of a conscious effort to bring in the users, try to work with them, make them understand the utility of the system by demonstration, experiments, and ultimately create, along with them, an operational system and make them place a demand on the organisation with respect to futuristic system. This has been, by and large, successful in many of the applications that you see today. I should remember my predecessors who worked for this and created such a concept which, I think, is extremely important in the context of what we are discussing in this seminar, that is, how do we use science and technology to bring benefits to society and how do we institutionalise some of these ideas. So, here is an example and an experience, which, I am sure, would be good to look at, study, and see whether it could be even adopted in similar circumstances.

Science, Technology and Environment

SUKUMAR DEVOTTA

Dr Sukumar Devotta: Thank you, Professor Gadagkar. I would like to thank the organizers for giving me this opportunity to talk on one of my favourite topics. I just used the topic of the seminar, but added environment because all three are intertwined.

If you want to produce something, you have to have industry. You have to use resources and then you have to discharge some unused resources into the environment, and there is some degradation of the environment. Most of the industries think that if I want to spend something for the environment, then there is no return on my investment. My investment is to produce products and make money out of it. But if I have to put some additional investment on the environment, then there is no return on investment, because the return on the investment comes to the society and I do not get much for it. So if I can avoid it, I save some money for the company.

And we are in the age of consumerism. So we are overspending on anything that we do – throwaways and things like that – and therefore the common man is confused. How do you solve this problem?

I must say that when the industry in India started, we were worried about the production. We wanted to have import substitutes, we wanted to have indigenous production; therefore a lot of emphasis was on the technology, but there was very little emphasis on environmental protection. We kept on producing, starting from aspirin and many pharmaceuticals, agro-chemicals and polymers. So now we have technologies, but we forgot that when these industries were increasing, we were degrading the environment to quite a significant extent. And we are still using some of these old technologies and now our problem is: how do we retrofit these industries and solve the problem of environment?

Although I will be talking about air, water and land, flora and fauna, one of the neglected areas, and only now you will find that it is being projected as one of the major eco-concerns and therefore, in all the EIAs, the bio-diversity is being looked at. But still, if you give the opportunity, then everybody will say that well, if you want industry, you have to cut some trees and forests or encroach into biodiversity areas. Still, it is not an area where people give a lot of consideration while going for development.

We have harmed nature because all our technologies in the recent past have been resource-intensive. Could they not look into alternative resources? We went in for rapid industrialization; so we are in a much better and happy situation in terms of GDP growth. But, as I said, we have harmed nature because of the rapid industrialization without considering environment as a major component.

We are into major use of synthetic materials, which means that production and use of these materials pollute the environment. Plastic is a classic example. If you take any city, you have a lot of problem with respect to unplanned urbanization, and therefore the environment is also degraded. I will talk about that later.

So as a society, it is our duty to safeguard the environment. As I said, if you want to make a product, you need some raw materials as well as support systems like water – one of them. Then, if this raw material is not converted into a product, it has to get into some other stream. It will be either in the form of a gaseous or a liquid or solid. And you need to use energy and some of this energy is wasted. You could be using energy to heat air – then it goes as hot air. This means you have used energy, but you have not used it fully. So if it is not a product, it is a waste. One of our primary aims should be how to avoid waste. So waste-minimization should be the basic dictum of environmental protection.

Just to give a kind of thought to this topic, in society, science gives a lead to technology, because there is no technology without science. And technology leads to protecting the environment, or degrading the environment. Invariably, if you put up any industry, it is bound to have some impact on the environment.

As per the law today, when you are going to start an industry, the proponent has to have what is known as an EIA (Environmental Impact Assessment) where all the aspects of environment – air, water, land, social and biodiversity – have to be looked into and the proponent has to say that he will safeguard these aspects and will make an environmental management plan, or what we call the EMP. He undertakes the commitment that he will do a-b-c. Only then the clearance is given, the problem is, it is very rarely monitored between what he promised and what he is doing. And that is where the environmental degradation starts.

Therefore, technology leads to environmental degradation, but it also gives you certain technologies to protect the environment. That is also there. For example, ESP (electro-static precipitator) is also a technology. We are not able to retrofit ESP into power stations, because this system is big and you cannot fit it to an existing one – an old power station. But in a new power station, you can get very good technologies where very little particulate matter escapes from the power plants. So you have technologies to do that, but you have no technology to retrofit to existing old units. So technology leads to environmental protection, and it can also fail to lead to environmental protection.

Science also has a lot of developmental knowledge base generated for protecting the environment, but many times, we do not convert science into technology for environment. Most of the time, science-to-technology conversion is for the production of products rather than for the protection of the environment. And in India, we have very little investment on technological innovations for protecting the environment.

If you have a factory, it has a lot of emissions – as I said, gaseous, liquid or solid – and they have many effects, particulate, SOx and NOx. But most of the time, a project is evaluated on how much product it can make and what cash it can fetch. We don't cost the environmental protection as a part of the project evaluation. Even today, it is so. Only because the Ministry of Environment wants to see what you will do, you may show some calculations. But actually, you will say, let me start the plant and I will put it later.

For instance, I can give you an example. We went and saw – inspected – one industry which has been working for 45 years without the rudimentary effluent treatment plant. And he was discharging water at 55° Celsius and 1.5 pH, along with a lot of particulates, into the sea. And he said, "Nothing has happened. We have been doing it for nearly 40 years". It is a public undertaking. What happened is that originally, they had agreed that they would do it, but they never did.

It is an irony. And you can see that in many places. There is a pristine environment in Maharashtra. There is a case going on. The industry was asked to go for desulphurisation. They said okay, but desulphurisation is an expensive unit; so we will first start the power plant and then do it. It is Ten years since they have been operating, and still that desulphurisation has not happened. A court case is going on, NGOs are fighting and we are also saying that it should be done. But they are saying, it is not economical – and we are using low sulphur now, therefore there is no need. One can have hundreds of arguments. The industry tries to get away saying that we cannot afford because it is costly. If you had internalized the cost at the beginning itself, then you would have realized that the economics is not that attractive, so I need to re-work on this total package.

And you have exposures. One of the other costs to the society is the diseases caused because of these exposures. Nobody pays for it. Only society pays for it. If you take a power plant in Delhi, it is in the heart of the city and could be spewing out a lot of SOx and particulates, and particulates are a major source of diseases. You know, they say that in Bombay, majority of the cases of asthma are caused by particulates from transport. Particulates go right into the lungs – PM-2.5. We are only monitoring PM-10. Who pays for these disease burdens? Society pays. And the industry does not account that into its calculations. One only looks at the economical efficiency. One calls it economic efficiency – between what I make and what I sell and what I invest – but we do not look at ecological efficiency – how much product I use, how much of the resources I use, do I use it completely and have I internalized all the externalities?

So if you take today's environmental situation, while we do quite a lot of things, I just want to say that currently, most of the Indian environmental protection regulations are due to judicial interventions. We have hundreds of laws. We have regulators. But they have failed to protect the environment. Ultimately, PILs have been the major cause of environmental protection. If you take most of the regulations today, they have come out of only a few people who have fought against the regulators and introduced many major laws. If you take the Municipal Solid Waste Management Rules, 2000, it is because of one PIL. But still the rules are not implemented. Let me say that. But the Municipal Solid Waste Management Rules, 2000 came into being because of one PIL.

Likewise, the Hazardous Waste Management Rules in 2003 was modified because of one PIL. But all states are not fully complying – let me come to that later. So what I am saying is that judicial activism has led to a lot of rules and regulations, but we still do not have the wherewithal to implement them. And then, we have too many regulations and too many regulators, and they have been very counter-productive. Therefore, I would say that we are in a kind of mess with respect to rules.

If you take a factory making a chemical, a Factories Inspector will talk about how to store those chemicals or how much inventory you can have and all those regulations. The CPCB – the pollution control boards – will say what you can emit and what you should not emit. And then industries will talk about how much product we can produce. There are too many rules and regulations – and regulators – and the industry wants to produce in spite of that and they want to make money, because ultimately, the bottom line is making money. Therefore, they try to avoid all these people coming to their factory. They would be happy if they didn't come. And the policy makers do not look at whether what we are doing is sustainable and does the region have the carrying capacity for this demand on the environment for the resources. We still do not have region-based regulations. I do not want to define this, but you know that sustainable development is now coming in a big way even into most of our policies. But if you take the last 50 years, we have not considered this aspect at all in industrial development.

The 1992 Rio Convention talked about prevention, precaution, common but differentiated responsibility, openness and polluters pays principle. Some of these things have happened in global policies, but not within India, for instance. We still do not have the polluter pays principle, whereas in Montreal Protocol and climate change, we have the polluter pays principle. In the Montreal Protocol, the developed countries paid the developing countries to phase out ozone-depleting substances. In the Kyoto Protocol, the developed countries are not paying, but still footing the bill to reduce the greenhouse gas emissions from the developing countries.

So these regulations are there, but they are not there within India – within our country. And openness is one thing that global protocols demand. Every country in the global protocols has to say how much ozone-depleting substances they are using and how much greenhouse gases they are emitting. They have to say this if they want to be a party to the protocol, whereas in India, within our country, we do not have this openness. Only now the rules are coming into play that we have to put outside our premises that this is what we are handling today – so much of benzene, so much of chlorine. Particularly if they are hazardous chemicals, you have to put it outside your factory premises that these are the hazardous chemicals we are handling. It is as per the rule.

Therefore, the transparency was lacking. You could get away with using all the hazardous chemicals, like in Bhopal, without the public knowing about it. Thus the society was at risk. And when we do risk assessment, we always say that it needs to be done not only for the site, but also off-site, because society should not be put to risk.

The liability clause is also very poor. The Public Liability Act came into being, but still many of the industries do not have insurance for public liability. It was only after Bhopal that this Public Liability Act came into being.

People should be looking at indicators for sustainable development. This is something, which has been coming – World Research Institute has developed certain parameters and I am just looking at environment. If you look at environment, some of these things will come into economic as well as social. So these social indicators are supposed to be developed for each country and you must look at where we are. In fact we are seeing that now each state is declaring or writing down the environmental status of the state. For instance, I was involved in the environment status report of Maharashtra. By 2006, they had to prepare a report and submit it to the Government of India. And we are saying now that each state should be having its own indicators for sustainable development to see where we are.

The other is the Millennium Development Goal, which many of the speakers mentioned. Although the Millennium Development Goal talks about health, water, education, etc., the Millennium Development Goal #7 talks only about environment – ensure environmental sustainability. And we are into 2006, but we have still not absorbed the Millennium Development Goal into our policies that well. If you look at all our policies, they still do not address these issues. 2015 is the commitment period. All Millennium Development Goals are to be achieved by 2015. If you take environment, we have not embedded the Millennium Development Goal in our environment policies.

MDG-7 talks about environment sustainability. I am more interested in targets 9 and 7. It says, 'integrate the principles of sustainable development into country policies and programs and reverse the loss of environment resources'. If you look at this land cover, it is still a major problem. I am from the Vidarbha region – Nagpur is located in the Vidarbha region – and Vidarbha has one of the highest forest cover. It is about 70%. But if you take Maharashtra, it is about 28%. Major resources, including coal and minerals are in this region. They are saying we need development in this region. But if you have to have development and extract these minerals, you have to go into the deep forest cover; and we have 80% forest cover. Only 30% is required as per the goal, so why don't we go for mineral extraction? But if you take Vidarbha as a part of Maharashtra, then it will go down in the 30% minimum. So people look at things very locally without considering some of these issues. And there is a political pressure to de-regulate the Vidarbha region, so that they can have deforestation.

These are the ways by which we try to tamper with some of the targets we ourselves set. The Millennium Development Goal talks about forest cover. And we just suddenly divide the same state into two regions and say that one region has got 80%, the state has got less than 30%, but still we will have deforestation just for the sake of development.

Likewise, let us take energy. We have never considered energy as a major issue and the Millennium Development Goal talks about energy use as a kilogram of oil equivalent and see what emissions occur. I will talk about it a little later.

The Yale Centre for Environment Law and Policy has published a report in 2005 and they have used certain sustainable indicators for the Government of India and are saying that they have ranked India 101st among 150 countries they analyzed. They have given a very poor score for environmental systems in India – only 23%. In the other areas, we are reasonably above 50%; therefore, if you see that, we have a very low environmental systems score. And we are ranked below some of the other countries; what it means is that we have the capability to do things, but we are not doing it. And our environment is degrading.

But there are some things happening locally. I always flag this – Corporate Responsibility for Environmental Protection. This is a voluntary agreement between Indian industries and the regulators. It is not a law; it is not a legal binding. It is a voluntary agreement. We call it CREP (Corporate Responsibility for Environmental Protection).

Seventeen of the most polluting industries have been identified and they are demanding quite a lot of resources for their survival. For instance, like chlor-alkali, cement, pulp and paper, leather – all these industries have been given their own performance targets. In terms of air pollution, water consumption, material consumption, they have been given their own benchmarks and asked to achieve these targets by 2006? If you take petrochemical complexes all over India – they have agreed to put certain norms and they said okay, we will try to achieve this. And, in fact, we are now using these norms almost like regulatory norms, although it is only a voluntary agreement. A lot of things are happening in that way.

But still, I would say that it is not something, which will take you to the world level. Some sectors have done well. Cement is supposed to be one of the best in India – in the world. They have done well. But still, on particulates, they are not that good. In terms of energy efficiency, however, they can match any cement plant in the world.

So there are good things happening, but we still have a long way to go in all the sectors. One of the major problems is that we still have small and medium enterprises in the areas where there should have been only large scale. For instance, we still have many small scale cement industries. They cannot achieve the same level of efficiency as of the large scale cement plants. So you have a problem of inequity.

Currently, the industry is going through a major change. They started production 20 years ago or 30 years ago. Technologies were not that modern. And now, suddenly, all norms are being updated. The pollution control norms that are coming today apply to the same industry. Therefore, they are in a kind of a fix. How do they meet emerging norms which were not there when the factory was started 20 years ago? How do they do that? It is a big challenge. Also, now that we are an open global economy, they have to meet, in terms of price, matching the best in the world. When they started, it was not there. They were protected. All chemical industries were totally protected. And today, they have to be competitive. I am a chemical engineer, therefore, I often use the chemical industry as an example.

Norms in India are very stringent – as good as some of the European and US regulations. Some of them – if you take dioxins and furans, we are putting 0.1 ng per Nm^3, just like EU. Sometimes I find that technology maturity is lower than the regulatory requirements, because we still do not have the technology to control or even to monitor, but we have put these norms into place. I will be talking about it.

Achieving productivity – if you want to be competitive on cost, your productivity has to be matching the best in the world. Coming to the responsive care – it involves a classical case of plastics, an external product. Now, Maharashtra has introduced, in 2006, a regulation – an ordinance saying that even plastic littering is an offence. And we are now going to the extent of saying that if somebody is selling a product, it has an extended product responsibility; that he has to take care for the entire life of the product. For instance, PET bottles. The manufacturers have to collect and dispose them at their cost; otherwise they will be fined.

So this extended product responsibility becomes a big issue for the old plants, where they did not consider these things and they just came into the market and started making money. Now suddenly, they find that their liability goes beyond selling. So it is going to be a very tricky thing.

We just did a study for an Oil industry. They are trying to sell kerosene in plastic pouches. The ministry said we have too many pouches and everybody is trying to ban plastics. But they said that kerosene pouches would make sense even for rural India because they do not get kerosene. And if it is given in one-litre pouches, they can be sold at a very convenient price without having any problem of distribution and the like. And they can store it. So there is a lot of marketing pressure to sell these pouches. But the issue is: do we need one more item to be sold in plastic, which is going to pollute the environment. A lot of people feel that the Bombay deluge happened because plastics. The plastic pouches might contain some traces of kerosene even after use. So we did a lot of studies, and then we had recommended that unless you want to take it as a policy issue, the extended product responsibility should be tried for this material as a test case. Tell the producer that they should be responsible for the pouch collection and disposal. So the producer is saying we will collect all these things. They will introduce this scheme in one state; they will take one city and state as a model and will try to collect these plastic bags and destroy them by incineration, and produce power.

You can produce power out of these plastics because they have a fairly high calorific value. If you go to Chemplast, which makes PVC, there the un-reacted monomer is burnt and they produce power out of it. So in one way they get rid of the very toxic vinyl chloride oligomers, but they also produce power out of it. So you have dual achievements – you get rid of the pollution as well as get some energy out of it. So the same will tried in the case of oil pouches. But everybody cannot manage that kind of situation. So it is an emerging problem for old chemical industries.

Zero discharge – water should not be discharged. You should be recycling water. It is a major problem. Not only do they put UF (ultra filtration) and RO, but then you must make sure that you treat this without... there is no coliform so that you can either give it to certain nearby places... this becomes a big issue. So we are doing a study on the reuse of water on land. Most of the time, the reuse of water on land is construed – the industry thinks – that as long as they put their discharge of water within their premises, they are okay. But it is wrong. If they are discharging not completely treated water, they are putting some of this unwanted contamination back into the environment – mainly total dissolved solids. That means the water is going to become harder in times to come. The soil also will become saline and will lose its productivity. Therefore, we are saying that there should be some standard for the land disposal of effluents.

The CPCB is saying, industry should try to achieve zero discharge. It is a very major challenge. Tirupur is a classic example. Tirupur, if you know, has a textile industry and they have been told that they must have a zero discharge because it is located, unfortunately, in Tamilnadu, where water is really scarce and polluted and one of the states in India where water is most scarce and expensive.

And the second is EHS practices. Now people are going for the ISO, OSHA, NIOSH certifications. While a lot of industries are doing this, still everybody is not able to manage that. And if you want to be in the international market, sometimes these are all marketing strategy – if you don't have it, you may not be able do business in a global economy.

I will just give you an example. I did a project for an American MNC while I was at NCL. They were buying the product from an international vendor for about $13 a pound. Being an American company, so they called it in pounds, and I still quote it in pounds. And they came to us asking whether we would be able to make this product at nine dollars a pound. We said may be yes, and we worked on it, and we got that product, almost with a new technology, at nine dollars a pound. And then they said we need a local vendor who can make it for us. So we identified a local vendor – one of the best in Maharashtra – and transferred the technology to him. Then the MNC came and saw the factory and how they would do it. But when they went and saw there, they said they could not do business with the Indian company; because his EHS (environment health safety) records are not that good. And although it is attractive for us – from $13 to $9 – with his EHS, we do not want to do business. If he has to do business with us, he has to have better EHS, which will be inspected by *our* group. It took eight months more for us to work on that company to improve its EHS. But for the last four years, they have been doing it, and the business is totally export-oriented. It is one of the best products NCL has produced.

So some of them can manage it, some of them simply cannot manage it, because they have been doing it for the last 30 years. As a chemical engineer, I will talk about reactor, cooling, etc. But if you go to some industrial estates, they will be using a drum as a reactor and the cooling is done by throwing water onto the drum. That is the cooling method. There is no control on it. Still, they make a good product, which can match some of the best in the world. Because the product does not know how it is cooled as long as it is purified later. They will pollute more because they have to produce and purify it, but the production is still the same. So you will find that this is not an easy for small and medium enterprises.

There is also this judicial over-activism. I would say all industries today are faced with this judicial activism. Sometimes, we do not want activity. I put NIMBY (Not In My Back Yard). I will tell you – there is this one company, which is fighting a case in Tamilnadu, in court. As per the rules, each state is supposed to have its own disposal facility for hazardous waste. But they go to court and say that this is not the right location. You cannot have it.

Many of the states still do not have this facility and these include Karnataka and Kerala in the south. This is because most of the time, somebody will go to court. Only yesterday, I read in the newspapers that in Karnataka, the State Minister for Environment has announced that a location – on which they spent a lot of money to identify and prepare – has now been shifted because of some sensitivity of some temples located there. And he is now saying we will give a hundred acres in some other area. Who will foot the bill for again going through the entire rigmarole of EIA and everything for this? That is because of over-activism. And we yield to certain pressures. This, I find, is a big problem to meet environmental regulations.

If you take the international agenda, you find that a lot of interesting things are happening – renewable energy, hydrogen economy, material economy, green engineering, green chemistry, doing away with subsidies and a lot of policies geared towards the environment. We are also doing a few things, but we still have a long way to go.

There is a report prepared by the UN, and it says that we have a very severe impact of pollution in the next couple of decades. Unless we act very fast and take a lot of initiatives, this is not going to improve. And you will find a red flag for India.

So let me come to water. The UN report says that India will be one of the worst affected in the next 25 years, in terms of water scarcity. It is the physical scarcity because we draw too much of ground water. I'll just tell you how much we draw. Yesterday Dr Goverdhan Mehta also mentioned that we over-extract from the planet earth. India drawing water for agricultural use alone is 80%, whereas it contributes just about 20% to the Indian economy. So where is the equity? We put conditions on industry to have zero discharge and zero extraction and to find their own water sources through desalination, whereas for these, there is no control at all. Anybody can extract water; they get free electricity and they use the water as they please, and there is no equity – they contribute much less. So I think we need certain equitable policy decisions on ground water extraction between agriculture and non-agriculture uses.

Because of the past sins, most of the waters are polluted – most of the rivers are polluted. CPCB has come out with a report. It says – it is a very interesting thing – industrial zones are in water-stress regions. If you take Tamilnadu, you will find that the Ranipet industrial estate continues to operate, although their water is completely contaminated and you have – a saying about this region– a river without water – because there has been no water in that river for the last 25 years. But that is where the industrial estate is. We continue to operate in such industrial zones.

The small and micro enterprises are only discharging 5%, and large industries are discharging 95% of the wastewater, polluting the water bodies. And most of the surface water bodies are polluted; the dark rivers are polluted water bodies near Kanpur, near Vapi, near Ranipet – Cauvery water in Erode etc. And ground water pollution and depletion are due to industrial activity. What I say is that today we put a lot of pressure on industries to find their own water and making the water reusable.

The reason is that we do not value water. We give water to everybody at one price. As long as you are a domestic user, you hardly pay anything, whereas industrial users pay something. But still, it is the same across the state. It does not matter where he is located and what he is using it for – whether it is a water-intensive industry or that he is not a major user. If you take pulp and paper, it is a very water-intensive industry. Sugar is also a water-intensive industry. So we must have certain policies as to where to put sugar and where to put pulp and paper plants. We do not seem to have that clear policy. We need to have a differential domestic and industrial water tariff and we have to cost water. If you take a European country and India, you will find that we cost water the cheapest in the world. That is why we have the problem of water scarcity. I was told that our costing of water is one of the lowest in the world. So we do not value water to its real economic value.

Water loss is one of the issues. We were told was that during distribution itself, like the T&D losses in electricity distribution, here too, the T&D losses are very high in India and nobody monitors it. We only monitor how much water we are treating, but we do not monitor how much water we ultimately send to the user point. So there is a tremendous loss in transmission and distribution because of the leakages.

And we still do not have any policy for rain water harvesting and artificial recharge. We only talk about buildings, but then we should be talking about industries and municipalities to take these responsibilities for artificial recharge and rain water harvesting.

We still do not use water auditors; one of the mandatory things. We talk about environment audit. Water audit is a very small component; we do not look at it as a major component. And we do not benchmark specific water consumption. The Millennium Development Goal talks about benchmarking and says can you do this; CREP also talks about it. But still, if you ask what the water consumption in your factory is, they will only say that from last year we have done this and that. And if you ask him what is your neighbour's or competitor's value, he may not know. So we do not benchmark water consumption. And some of these industries are very water-intensive; so this is where we can save quite a lot.

We are not following cascaded water use. We may use water, and the same water can be used for some other purpose, but we always do a one-time use. We use it, and then it goes as a discharge, whereas the international trend now is to see if it can be used in a cascaded way. If water is used for one application and it is still good enough for another application within the premises, then we do it for a third and only then it becomes unusable and goes to the treatment plant so that we can reuse it. We should be looking at cascaded water use.

There should be location-specific norms. We have one norm all across India – it does not matter whether it is Karnataka or Tamilnadu or UP, we have only one norm. And sometimes, the State Pollution Control Boards might use stricter norms, but this happens very rarely. They adopt whatever CPCB says. So we are not looking at location specifics. Say, this region is stressed. So should we have a more stringent norm? We do not do that.

To renovate water from wastewater is a very interesting concept. For instance, Chennai Petroleum has put up a very huge RO plant – 2.1 million litres per day – renovating water from sewage. So it is possible to get virtually drinking quality water from sewage water, if you want it. There are technologies available. Just two membrane technologies – ultra-filtration followed by RO. But it is not being followed because it is still expensive in the sense that somebody has to take it as a mission. But if you want to take it as a societal mission, then it is possible that you can get recycled water – virtually sewage water. So, industrial wastewater recycling is very much feasible.

And there are newer technologies emerging on desalination processes, like the one from deep-sea water extraction and flashing, coming in Tamilnadu. It is a very interesting concept. Maybe more such technologies and more such demonstration plants have to come in.

In some areas, we have the problem of arsenic and fluoride. A lot of scientists are working on it. If you look at arsenic removal, you will see hundreds of papers coming from India. But then, if you ask them if this can be converted to technology, the answer is no. They have only used certain materials, they will know they can do it in bench-scale, but when it comes to real technology, it is not there. There is hardly any technology. We are now re-evaluating a couple of technologies from the US and we are also working on some of these for UNICEF in India only for arsenic and fluoride. So, for the first time, we are doing it on the community level. It is not a tap level. As to how to incorporate it in the community level, we have done it for fluoride for electrodefluoridation. But we are now doing it through a bed of modified zeolite as the material.

Air is a big issue in some of the cities, but the power sector and transport are the major polluters. Particulates are the major pollutants, and all cities – most of the mega-cities as well as Class I towns – they are all monitored. But you will find that they are only monitoring in certain cities for certain parameters but emerging parameters are not looked at. If you want to know what the mercury level in Bombay is, nobody will know, because that has not been monitored. And Delhi could have a high level of mercury because it has a power station right in the city. You could have PAH (polyaromatic hydrocarbons) and dioxins and furans. But we do not monitor some of these emerging pollutants.

And if you take all these parameters that CPCB puts out every year, there are regulations. Most of the cities are not complying with the particulate matter. We publish and we say particulate matters are bad. But still it is above the limits in Delhi, Kolkata, Hyderabad. We do not do anything about it.

One of the major reasons is diesel – diesel engines. And although the Mashelkar Committee has worked on Auto Fuel Policy and India is reducing sulphur in diesel, diesel particulate remains a major problem. Our cars are old, and we do not have diesel particulate filter technologies in our cars. Another is carrying capacity. We just keep on introducing more and more vehicles. In just a matter of ten years, the number of vehicles in Delhi has doubled. And you still use a huge quantity of diesel. You cannot have an old vehicle operating on diesel and expect particulate matter in a place like Delhi to be under control.

We still have a problem of controlling air pollution from industries because these industries, for instance, the power plants, have been set up some 20-30 years ago. And if you want to put in some of these emerging modern electrostatic precipitators, they require so much space that most of these plants do not have the space to retrofit. That is one of the reasons why our power plants do not have ESPs.

On hazardous waste, there are rules and regulations, but I can tell you that only three states have the TSDFs. Maharashtra produces about 40% of India's hazardous waste. And Maharashtra has two facilities. Gujarat has about ten facilities. Karnataka, Tamilnadu and Kerala are yet to have one. Andhra Pradesh has one. Only three states in India are complying on this hazardous waste disposal. What are we supposed to do? We are supposed to create facilities, which will accept hazardous waste from industries and dispose of it in a scientific manner.

But if you go to the industrial sites, this is what you see. There is a 1.5 million tonne of chromium sludge being dumped, and for more than ten years, it has been lying in the open. This is in Tamilnadu. And you can see that the water is completely polluted. Every day, you can get chromium leached into water. And in that entire area, the water stretch is unusable. You cannot touch it, because it can have as much as 200 ppm of Chromium 6. And that is the problem. Then you will find many such dump sites, illegally dumped.

There are areas where industries have taken some responsibilities. One classic example I will give you is that of Zuari Agrochemicals in Goa. They were storing about 250m^3 of arsenic for the last 35 years because they did not know how to dispose it off. And they were just keeping it – until the Supreme Court Monitoring Committee went and told them they could not keep it for ever and had to do something about it. NEERI was given the job and we did it as per the USEPA – converted everything into a solidified form and disposed in a landfill, designed with extra precautionary principle, and we gave them the total disposal technology. It was done within 45 days. So you do get some developments like these, but these are very rare examples.

The Montreal Protocol is a classic example where 'polluter pays' is concerned. But it also gave some extra fillip to the environment. Technologies to phase out ozone-depleting substances brought additional benefits. When they brought refrigerators, they not only phased out the ODSs, but they gave better, energy-efficient refrigerators. So they are not only with non ODSs, but also are better efficient. Sometimes you get co-benefits when you deal with the environment and we should capitalize on that. So we are now working on CDM (clean development mechanism) for GHG reduction and I am sure that we should be looking at better technologies.

India is a party to the Kyoto Protocol and we are looking at CO_2. And one of the issues about CO_2 is that it is mostly coming from power and in the Indian inventory of greenhouse gases, you will find that CO_2 is a dominant – 65% of the Indian greenhouse gas inventory is carbon dioxide. And the bulk of it comes from energy. Therefore, one concern for the future is the energy intensity of the Indian industries. And if you look at it, our economy is very highly energy-intensive. This is expressed in metric tonne of carbon dioxide equivalent per GDP dollar. And you will find that we are one of the highest in the world. If you take the former Soviet Union away, we will be in the top five. Therefore, we need to look at options to de-carbonize our economy. After 2012, when the Kyoto Protocol goes for re-negotiation, and Bush (US) is not going to leave India and China out of it, they will want some commitment from a country like India. Although we can politically argue and negotiate, this will be a major point for us to ponder – how do you reduce the carbon-intensity of your economy?

As for energy growth, yesterday there was a brilliant presentation on nuclear. Our energy growth is five times the world energy growth – 5.5% - whereas the average energy growth is 1.1%. Naturally, US and Europe will seek some assurance from India that we will do something about our energy growth and carbon intensity. So, we need some strategy for expansion on non-renewable energy sources. They say that by 2025, India and China alone will be consuming 75% of the world's coal. Coal will continue to be dominant, but that will also mean a lot of pollution because our coal is high with ash and sulphur. Therefore, we will have to handle pollution in a major way, if we have to continue with coal domination. We also have to look at other options.

One thing I want to flag here. Hydropower was considered to be very safe and very environment friendly. There is a recent controversy that these dams produce as much methane and CO_2 as CO_2 in thermal power generation. And we are now doing some studies on Hydropower projects. We will be measuring the methane emission from hydropower dams.

The future fuel, they say, is going to be hydrogen. There is a kind of a world energy growth pulse. They say that we started with coal and technologies were based on coal, followed by oil, followed by gas. The future will be hydrogen. We are doing quite a lot of work on hydrogen, but not in a big way. The USDOE is putting something like $100 million and Bush has put in $2 billion just on carbon capture. That is the kind of money they pump in. What we do is very little, but still, we should be looking at hydrogen, at least in a more concerted way than what we do today. We are doing very miniscule work on the hydrogen economy.

One of the advantages of hydrogen is that it produces water when it burns. The fuel cell has a lot of scope for a country like India. Particularly, large-scale, high temperature fuel cells have a lot of scope, because here the efficiency is very high. It can be as high as 60%, whereas a PEMF (proton exchange membrane fuel) cell will give you not more than 28-30%, just matching that of generators today. But the complexity increases with size. Removal of CO from hydrogen is very important for proton exchange, whereas that is not an issue for solid oxide or molten carbonate fuel cells. So for large capacities, you can use this kind of fuel cells with very high efficiency, easily touching about 55-60%, whereas here it will be difficult and also more complicated. Fuel cell is what most of the people are looking at for automobiles, but I feel that we should be looking at it much more.

We should have a priority for waste minimization because prevention is better than cure, as everybody knows. So we should be looking at cleaner technologies more than end of the pipeline approach, creating wastes and trying to dispose them. We should be looking at the intermediate stage and the priority should be for prevention. Only the last priority should be for disposal.

We should also be looking at integrated industrial complexes where waste from one is raw material for another. As a classical example, I can speak of say, a sugar mill, distillery, and pulp and paper, which can be put together, so that the bagasse is used in the pulp and paper mill, the alcohol produced is also used for a chemical complex. You can have four industries in one complex, where you do not bring in external power – you produce your own power. You know, today people say that a sugar mill will no longer be – need not be – called a sugar mill because the power will be a major output of the sugar mill, rather than sugar. Therefore, we should be looking at integrated sugar complexes with distillery, pulp and paper and chemical complexes, so that we can reduce pollution as well as energy requirements.

About challenges for S&T, I do not need to say much, but I feel that we should be looking at biotechnology, in a big way for remediation. We are trying to save this universe and we are trying to avoid pollution. And biotechnology will play a major role in remediation. In some of the projects in which I am involved, we are using *in situ* remediation only through biotechnology.

Green chemistry should be promoted. We have a very good green chemistry program, but not many good projects are coming in for that. DST has a special program on green chemistry. Very little green engineering is done in India. We do not talk about green engineering at all – we talk only about green chemistry.

We need to address these issues – this is my final slide. We have too many regulations and regulators and this has been counter-productive. We need to find out how to integrate them and to make one person responsible – one agency responsible – for environment protection. We have to have technology and protocol maturity before regulations. We sometimes tend to be over-enthusiastic. We put up a regulation without knowing how to control it. I can give an example. I keep talking about dioxins and furans. We have put dioxins and furans in regulation whereas we have no facility in India to measure them. No Indiantory can monitor dioxins and furans to the level it is needed – 0.1 ng per Nm^3 as per international norms. It costs about Rs 30,000 to 70,000 per sample, if you want to do it outside India. Who will pay for it? We have incinerators all over India. This is just one classical example.

We have a very low R&D budget for environment protection. As I said, environment protection is not an issue – making a better product for industries, is an issue. And if you want to take money from any government agency, and if you want to put up a pilot plant for environment protection, there is a lot of confusion about funding. Each will say that maybe MOEF is the funding agency. They will fund for monitoring. They will want to know where the pollution is, but will invest very little for technology development like DST does.

We do not internalize the externalities. As I said, we are still taking environment protection as an external parameter. We do not look at the polluter pays principle. We fine industries. We have fined Rs 29 crores to a polluting industry, but that is a private industry. We cannot fine municipal bodies for polluting water. Most of the pollution today is because of the discharge of untreated municipal sewage and municipal solid waste. We cannot fine them because they are municipal bodies. Somebody might say why not? Maybe we should consider.

On the conversion of science to technology, we have a lot of science on environment protection, but we do not convert that into technology, as Prof. Valiathan said.

We need to integrate sustainable development in our financial and developmental policies. We have still not taken that as a major issue and we seem to go along with the development in the area rather than looking at sustainable development. Gujarat is a classic example. We are saying that we should be looking at the carrying capacity of the region – we cannot keep on putting up petrochemical complexes there.

We need to encourage investment in pollution abatement because it is still a lot of money for industry to invest. I do not want to talk about it – everybody knows it, and time is running out. We have to save this world with a lot of our joint efforts. Thank you.

Challenges in Higher Education in the Face of India's Demographic Ascendancy

P RAMA RAO AND B K ANITHA

INTRODUCTION

The unprecedented expansion of higher education has affected many other institutions in the larger society. Both internal changes as well as external changes of the institutions of higher education have come to the forefront in the process of massification of higher education(The Economist, 2005). Most significantly is the character of student aspirations, modes of governance, student teacher interaction and the varied forms of finances. The resurgence of the importance of research in university education has further increased the complexity of the relationship between teaching and research within the context of the university education. At one end, the university education within the Indian context has and continues to enjoy a secondary status. The increased competition for funds for research has left the university system devoid of even a working proposition of funds that is required to even engage in a semblance of research. The internal structure and organization of universities has always emphasized teaching as its primary role with a considerable over burden of administrative functions, given the bureaucratic ways that universities in India function.

Research activity in India is to a large extent considered as an elite activity. Though the number of people engaged in research is gradually growing, it still requires intense socialization in an academic discipline. Additionally, as stated by Gibbons(2005), universities will have to adopt to the 'Mode 2 knowledge production' that requires a close working relationship between people located in different institutions and typically include business people, patent lawyers production engineers outside the university system.

The complex interrelationship between globalization, international competition and collaboration need to be understood and put in perspective, when one engages in analyzing the higher education system of any country. Competition no longer, solely, takes place at the level of making products or providing services in order to increase market shares, rather competition in an environment of alliances and collaboration is shifted to the second level where there is a pressure to innovate. Competition now in the renewed definition is between design configuarations and the ability of firms to develop their potential increase resourcefulness and enhance creativity(Gibbons,2005; Krauss G,2006).

The process of institutionalization under the conditions of the dynamics displayed by the current knowledge production will have to receive increased attention. All said and done the universities still remain the core centre that is responsible for the training of these large number of specialists. The new form of knowledge production impinges on the existing institutional structures. It is of interest to understand how universities cope with this new expectation based on a clear shift of the process of knowledge production, where the university is not the focus, but individuals and competencies become the central categories of analysis.

The challenge is further made more difficult since there has been an expansion of the higher education system, where not only the kinds of institutions engaged in this business has increased but also the very numbers of universities has grown . It is not the size of these institutions that pose a challenge but the varied functions of these new kind of institutions. Under severe budget constraints no institution can work in isoltionThe new institutional landscape of knowledge production is marked by academic disciplines showing increased fuzziness at the boundaries. In many areas whether natural science project like the human genome project or for that matter social science where there is increased engagement with real life problems that necessitates one to cross disciplinary boundaries. Interactions between science technology and social issues have intensified.

The greatest challenges in today's world is also the management of disciplinary identities in trans-disciplinary settings and the development of trans-disciplinary capacities and the new dimension of quality control in the scene where there are several standards as there are diversified types of institutions.

HIGHER EDUCATION IN INDIA

The greatest challenge to higher education in India rests on the fact that the world economy is becoming more complex with increased globalisation. In this scenario, the new paradigm of knowledge economy is gaining predominance. Historically, India was largely an agriculture-based economy. One can without any hesitation claim that the colonial rule to a great extent was responsible for India not being able to take advantage of the Industrial revolution. Indeed, the country was a mute witness to the rest of the world experiencing unprecedented prosperity through industrial revolution. After the colonial rule and having gained independence in 1947,India, has made a conscious shift, to moving towards an industrial economy.The time lag has resulted in India paying a heavy price and the initial gap has proved very difficult to be filled.

However, this is not the case now, as the world moves into the era of the so-called knowledge economy, India is an independent sovereign nation. The strides we have made over the past three decades particularly in the field of science and technology has in particular positioned India at an advantage to excel in this new knowledge-intensive society. Will India succeed in doing so? We all should hope that it would. If it does not, it will be an immense tragedy. And we shall have no one to blame except ourselves.

If India is to seize upon the unfolding opportunities provided by the knowledge revolution, then one will have to not only engage in a critical assessment of the our higher education system but also on the interplay of related factors that will impinge on the system both directly as well as indirectly.

First, let us look at the economic prospect. A recent report of Pricewaterhouse Coopers points out that by 2050 (Table 1), in US dollar terms, India will overtake Japan and the UK, and, in PPP terms, the Indian GDP will be equivalent to that of the United States. Besides this promising economic prospect, India is likely to attain demographic supremacy in the world. The UN world population prospects database 2004 suggests that the working age population, which is 15-59 years, will increase only in India while in all other major countries, it will decrease (Table 2). Consequently, nearly one in five of the work force in the world will be an Indian.

Table 1:
Comparison of Current and Projected Gross Domestic Product of Selected Countries

Country	GDP in US $ terms		GDP in PPP terms	
	2005	2050	2005	2050
USA	100	100	100	100
Japan	39	23	32	23
China	18	94	76	143
UK	18	15	16	15
India	6	58	30	100

*Source Pricewaterhouse Coopers Report: World In 2050

Table 2:
Comparison of Working Age Population (15-59 years)
Among Selected Countries

Country	2000(%)	2050(%)
India	17	19 -
China	23	14-
USA	5	5*
W. Europe	3	2
Japan	2	1

*USA adds qualified people significantly by its liberal immigration policy.
Source: UN World Population Prospects Database 2004

This is a tremendous opportunity and a challenge for India to utilise this vast human resources base. Training this enormous human power will require the nation to overhaul the existing education system that focus on memory based learning to that of developing analytical and technical skills for research and development leading to innovation. Unless we are able to achieve the goal of building such skills in good measure in hundreds of thousands of potentially able, young population, it is impractical to visualise India as a prosperous nation.

It is interesting to infer from the data presented in Table 3 that academic R & D, expressed as % of a nation's total R & D expenditure, correlates with a nation's wealth intensity (per capita income adjusted to purchase price parity). India invests about 3 to 4% of India's total R & D in academic research while for the US, which is nearly 15 times more prosperous than India, the corresponding figure is 20%. Given the fact, that the R & D expenditure of the US is 30 to 40 times more than that of India's; it is surprising to note that the absolute differentials in academic R & D between the two countries is more than a factor of 200. This only suggests that there is an urgent need to substantially increase the investment in academic research which necessarily will include a huge increase in the number of trained scientific personnel. The universities in this country must be converted to a resource base for scientific trained human power. Additionally, it has also been pointed out that in today's knowledge based economy, creation of intellectual patents(IPs) as well as utilisation of IPs is extremely crucial for any country to stay ahead in this competitive world(Narayan Murthy, 2007).

Finland, although a small country, presents an interesting case. Nokia of Finland alone invested 1% of the GNP of Finland into its R & D, for which Finland draws *intellectual resources from its university system*. No wonder Nokia, and the likes of Nokia, have succeeded in transforming Finland's forest-products based economy into technology-intensive economy. A recent UN report applauds the success of Finland as a role model in the way it has integrated science, technology and industrial policy to develop an innovation policy for the country.

Table 3:
Comparison of Selected Countries in Relation to Wealth Intensity and Investment in Academic R&D (2002-03)

Description	India	South korea	Finland	USA
No. of Universities (Population)	370 (1100 million)	120 (45 million)	20 (5 million)	1800 (280 million)
R&D as % GNP	~1%	3%	3.5% (Nokia alone 1%)	2.8%
Academic R&D as %Total R&D Expenditure	3%	11.5%	18%	20%
Citations to all papers to National GDP	<0.02	0.07	0.44	0.25
Wealth intensity (PPP adjusted per person)	2880	12000	27,100	37,500

Academic R & D and wealth of nations correlated. UN report applauds Finland's model of integrating S&T and industrial policies to develop an innovation policy; country transformed from forest based economy to high technology based economy.

Fundamentally, economists aver that the gross domestic product of a country, preferably expressed in PPP (Purchase Price Parity) terms, is obtained by the product N*Y where N is population and Y is per capita income. Y, which is a strong function of investment capital (k), human capital (h) and resources (r), can be expressed as ***Y= Tf (k,h,r)***, where T stands for technology by way of design and innovation of instruments, products, processes and systems. These simple concepts unambiguously emphasize, above all, the importance of what human resources can generate for a country.

In light of the fact, that human resources is critical to the wealth of a nation and that India is projected as the world's largest work force, it cannot but be overemphasised that harnessing this abundant human resource will require careful planning.

With the collapse of the Soviet Union, the world witnessed the emergence of the US as a single nation super power. The last decade particularly has shown the emergence of other countries forging their way to be a part of this super power. More and more nations are fast realising, that to remain in power will necessary mean building strategic alliances with other nations leading to a multi-polar power centre. As a result, a multi-polar world is evolving in which, United States, China, European Union, Japan, Russia and India constitute the important six nodes.

Political scientists predict that in the prevailing situation today, there will be no major conflict among themselves that will lead to a situation of war among these six nations. However, these six countries are constantly engaging in fierce competition within themselves. The emerging world order seems to suggest that this thesis is valid. Then, India, as one of six nodal power centres, has to develop into a credible competitor. How will that happen? Clearly, India has to invest its considerable ingenuity, resources and efforts in areas where the country enjoys a clear comparative advantage. And India's relative advantage resides in the wealth of its human resources.

CHALLENGES IN HIGHER EDUCATION

Higher education and research are basic to building human resources. The challenges facing the country can be classified into four broad areas. They are:
(i) increasing capacity;
(ii) improving quality;
(iii) minimising inequality and
(iv) internationalising of the education system.

INCREASING CAPACITY

For nearly fifty years prior to independence, i.e. between the years 1900-1947, there was practically no increase in enrolment rates in higher education. After India gained independence, higher education witnessed a visible increase, though incrementally during the initial period largely supported by the Indian government. During the late eighties and nineties, globalisation brought with it the need for unprecedented expansion that beckoned the participation of the private sector in education. Currently, around eleven million students are enrolled annually in higher education. This figure of eleven million in India in reality represents only about 9 per cent of the eligible age group. In other words, although we claim that enrolment rates have relatively increased in comparison to pre independence period, in actual terms, over 90 percent of the eligible age group do access higher education.

This is despite the fact that the country has over 370 universities. The number of universities in India when compared to some of more developed countries as well as to those countries who are beginning to make a mark is far from adequate. For example, it is shown in Table 4 clearly indicate the number of universities that

India should have in order to be at par with USA, UK and Korea. The comparative figures given in the table are drawn in correspondence to the population size of each country.

It has been reported that the National Knowledge Commission(2006), has drawn attention of the government to the relatively inadequate number of universities that India presently has. The National Knowledge Commission(NKC) has recommended an increase in the number of universities to 1,500 by the year 2015. "This is needed to attain a gross enrolment ratio of at least 15 per cent [of the relevant age group of 18-24] of the population from the present 7 per cent, which is only half the average of Asia." The Commission has also recommended the creation of 50 national universities as "exemplars of excellence"(Vishwanathan.S 2006). Obviously, the government cannot be the lone player for setting up this large enterprise. The private sector will have to be tapped alongside with new forms of partnership and collaborations to raise and manage the required resources. However, India has not yet instituted a modernised regulatory framework for an effective public-private partnership in establishing and managing world class universities.

Table 4: Comparison of Number of Universities and Population Across Selected Countries

Country	Population (in million)	No. of Universities	To Be At Par With The Country Of Comparison, The No. Of Universities India Should Have
Korea	45	120	2900
UK	50	170	3700
USA	300	1800	6600
India	1100	370	——

Source: T.H. Chowdhury(In a private communication)

Information Technology is a great leveller that can help in bridging the gap between those students who are enrolled and those who are yet to be brought into the fold of higher education. However, the challenge of using technology for widening the base of higher education is not so simple. It requires a great deal of thought and systematic planning.

Recently, Dr. K. Kasturirangan in one of his presentations at NIAS highlighted the details of the EDUSAT initiative of the Indian Space Research Organisation. He emphasized that this is for the first time all the elements of educational and training system has been brought into a single space platform. However, to fully exploit its potential, it will be imperative to create new institutional structures to bring together all stakeholders under one single authority. Further, stardardised ground system modules that would enable reception display, storage and down loading operations on one side and where required facility for interactive sessions have to be setup. A third important aspect is the creation of a wide variety of educational contents for applications related to teacher training, supplementing the ITI curriculum, enrichment of school and college education and curriculum based training for professionals. Integral to all this is the provision for posting news, views and comments that allows for continuous feedback.

A phased build up of capabilities and capacities is a must with committed resources. For example, 18 hours of broadcasting per day with 3 repeat broadcast will need about 7000 programmes in a year. This, in turn will mean direct employment to about 3000 persons and indirect employment to several thousand support persons. On the financial side, one can envisage investment of the order of 10-12 thousand crores over the next ten years in a phased manner. It is thus important to note that while EDUSAT draws upon the experience of years of distance education and training efforts, creating innovative systems on the ground, as for the project that is analogous to the use of other space based systems in India, that is remote sensing and communication, is the need of the hour in this case too. There is an urgency to review the related issues both at the governmental level as well as by other stakeholders in education and training.

Open Universities is yet another mode to reach out to the million eligible population who have been unable to access higher education. They have made valuable contribution to the expansion of higher education; however, the use of modern technology by open universities is limited at present and warrants expansion in a big way. Innovation in the mode of expansion is integral to meet the equity and quality goals of higher education

Among the several initiatives undertaken at the national level, the National Programme for Technology Enhanced Learning (NPTEL), the one that is supported by MHRD, is worth mentioning. Premier institutions in the country like the IISc, Bangalore and seven IITs have worked together to develop content in selected B.Tech courses in such a way as to render them amenable to multi-media-enabled as well as web-based education. The potential of this initiative need to be critically assessed and corrective measures to improve it's over all effectiveness must be integrated into the programme. In yet another initiative by IIT Bombay, with what is arguably the most successful distance education programme in which the lectures delivered in their institute as part of their own IT courses in their Kanwal Rekhi School of Information Technology (KReSIT) are transmitted using V-sat communication technology to remotely located regional centres. The success of this programme needs to be assessed with the viewpoint of it's impact as well as a detailed feedback for further improvement.

Thus, the country can list of a few laudable initiatives that have been attempted in utilising modern communication technologies to increase access as well enhance the quality of higher education. However, these efforts have been isolated and carried out at the micro level. Upscaling and substantially increasing the outreach to make a visible impact at the national level is a major concern. In this effort one needs to give careful consideration to the overall quality of higher education.

IMPROVING QUALITY

Historically, the Universities of Bombay, Calcutta and Madras were the first three Universities established in India early in the year 1857. Twenty-seven colleges that functioned in these three Universities marked the inauguration of higher education in India. At the time of Independence in 1947, there were only 20 universities and about 500 colleges. The student enrolment was around 2 lakhs. After six decades, in the year 2007, India has over 370 universities. These include affiliated colleges and other institutions of higher education. There has been proportionately an increase in the total number of colleges as well as student enrolment. The annual enrolment of students has increased by 17600.

Unlike many countries across the globe, the higher education in India poses a unique challenge. This is primarily because the Constitution of India has chosen to place education as a subject in the concurrent list. This will automatically mean that education in the country is shaped both by the numerous state governments as well as the central government, thereby empowering the Central as well as the State Governments to establish universities. The wide disparity in the socio-economic and education indictors across the different states also impacts the quality of the universities in their respective states. Thus, one can see the evidence of uneven growth of universities across different states in the country.

Apart from this, there is also a provision made in the Indian Constitution, to accord selected institutions, the status of 'Deemed-to-be' Universities. Under this provision, the centre and the state have several universities that fall under this classified group. In addition, some of the State Governments have also made provision within the legislation to create what is called private universities. However, there is, as yet, no Central legislation (i.e. by the Indian Parliament) for establishing private Universities.

On the other hand, the Central Government has also instituted a new category of Institutes called the Institutes of National Importance. Each of the 13 Institutes of National Importance has come into being through an Act of the Parliament. A more recent development in the country pertains to institutions which are imparting higher education but have not sought a university status. These institutions award only Diplomas. Most of such institutions are in the discipline of Business Management and Business Administration, of which the 6 Indian Institutes of Management (IIMs) and the Indian School of Business have made a name for themselves. The 370+ universities which have thus come into being are classified as shown in Table 5.

Table 5: Classification of Higher Education Institutions in India

Sl.No.	Type of Institution	Numbers
1.	Central Universities	20
2.	State Universities	203
3.	Institutes of Medical Sciences accorded University status by the States (AP : 2, Bihar: 1, J&K: 1 & UP:1)	05
4.	Private Universities established under State Legislation (Himachal Pradesh:1, Gujarat:2, UP:2, Uttaranchal:2)Note: Rajasthan has passed the legislation but no Private University has come up yet)	07
5.	a) Deemed-to-be Universities funded by MHRD (IISc, NITs, JNCASR, TIFR etc.)	38
	b) Deemed-to-be Universities which are self-financed	84
6.	Institutes of National Importance (IITs:7, PGIMS, AIIMS, SCTIMST, NPhE&R, ISI, Dakshin Bharat Hindi Prachar Sabha)	13
7.	Institutes which have not sought University Status and award Diplomas (eg: IIMs:6, ISB, IPE etc.) (More than)	08
Total	(More than)	378

The classification of universities indicate that India has experimented with diverse patterns of governance and now runs a complex system of 370 universities or more, the bulk of which are State universities. The relatively better institutions of higher education belong to either the category of deemed universities funded by agencies of the Central government, the Institutes of National Importance or the Management Institutions which have preferred to stay outside the university system. The State universities have grievously suffered from the system of affiliation. A large number of the more than 17,600 colleges are affiliated to one or the other State universities.The unfortunate result is that the State universities have in the process have been largely reduced to examination conducting bodies.

Additionally, some of the States have used their legislative power to enact and establish private universities. However, a large number of such universities have been denied recognition by the UGC due to poor standards. A small number of these universities,(See Table : 6) of the State-legislated private universities, although recognized by the UGC, have not shown any significant promise.

Table 6: Distribution of Private Universities Under State Law that are recognized by UGC

Name of the State	Names of the Private Universities
Gujarat	Nirma UniversityDirubhai Ambani Institute of Information Communication Technology
Himachal Pradesh	Jaypee University of Information Technology
Uttar Pradesh	Integral University, LucknowJagatguru Rambhacharya Handicapped University, Chitrakoot
Uttaranchal	Dev Sanskriti Visvavidya Pith, HardwarUniversity of Petroleum & Energy Studies, Dehradun

It is not surprising therefore that Amartya Sen commented recently at the Harvard Alumni Association Meet at New Delhi on 26 March 2006, that India has prematurely privatized universities.

Universities in India largely concentrate on teaching and do not have a clear mandate for research. This has been one of the primary reasons for the steady decline in the research output of universities. In the 1950s the universities accounted for 60% of research output in the country and fifty years later, the share of universities in the country's, research output has dropped to less than 10%.

The culture of taking out patents was non-existent in the university system for a long time. It is only recently that there is awareness of the importance of registering innovations through patents and the numbers still are not impressive. In nearly *ten years* since 1995, the total number of Indian patents filed by the educational institutions is less than 800. Internationally, for example in the year 2005, academic institutions accounted for over 5% of the total inventions in the world. Moreover, the governance structures of State universities to a large extent, and the Central universities to a lesser extent, have been adversely affected by inadequate funding and other related constraints.

However, it is unfortunate that, although India has a heritage of scholarship, today, none of the Indian universities compares with the best universities in the world in terms of creative outputs. *The question therefore is whether our country can even design an institute of higher education which will in due course acquire such a stature and come up with such outputs that will propel it to the league of the highest ranking universities.*

It will be therefore pertinent to raise the question, what are the attributes of great universities? A respected recent publication-Academic Ranking of World Universities brought out by the Institute of Higher Education, Shanghai Jiao Tong University, China in 2006 listed the top 500 world universities. While it may be a matter of debate regarding the way in which they arrived at the ranking, it still remains a fact that the positions of these universities will alter little with an alternative objective measure. Research and related publications has been central to the methodology adopted for ranking. It is interesting to note that 8 of the top-most 10 universities are in the United States.

Drawing comparisons with the US, is not necessarily since it is a model towards which Indian universities need to work towards specifically, but more so because it sets the default standards and may be useful as a benchmark to begin with. It is in this background that it may be worthwhile, to examine the key features that render the US universities to excel. Two features of the US education system stand out as key to excellence in the top US universities.

The first is that these universities are autonomous, and the person who heads these institutions display exemplary leadership capabilities(Hendrey G.D and Dean S.J, 2002). In an extremely educative analysis, Amanda Goodall of University of Warwick, UK has shown that there is a positive correlation between the research credentials of the heads of the universities and the ranking attained by the universities concerned. In his analysis, Goodall has studied the research performance of the Vice-Chancellors of the world's top 100 universities. It is remarkable that the rank order of universities follows the rank order of the research performance of those who head these institutions (Figure 1).

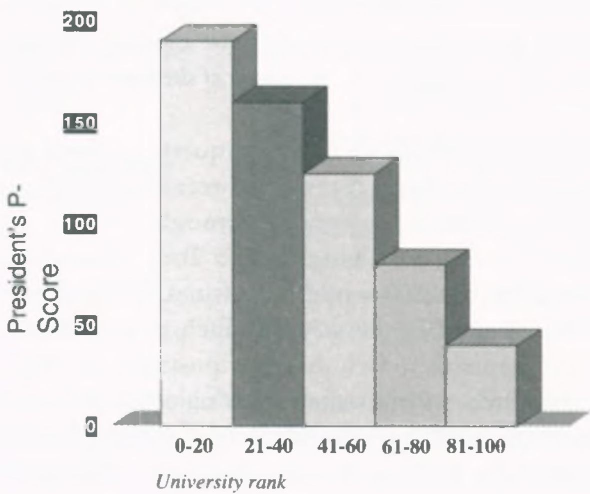


Figure 1: World Ranking of the Top 100 Universities and Research Credentials President's (P- score) of their Presidents are correlated

Source: Amanda H. Goodal ofWarwick university (UK)(2006)

This may not necessarily work one-way. Alternatively, when universities have faculty of very high credentials, they invariably look for a President with relatively higher research credentials. Having stated this, it still remains a fact that the President's score and University ranking are highly correlated. Unfortunately such a criterion is invariably not used while choosing Vice-Chancellors in our country.

The second feature underlying the unparalleled excellence of a significant number of US universities is that they brutally compete for high calibre faculty, which automatically leads to very able men and women being inducted as faculty in the top universities. The openness, flexibility and substantial funds of these universities are able to bring together some of the best minds from a variety of cultural backgrounds and to encourage individual initiative. By comparison, the quintessential reason for the failure of India's higher education system is the dearth of adequate number of high-calibre faculty. The unfortunate consequence of this serious deficiency is that while USA dominates in cited research publications and original patents, India's performance by comparison is poor. It is not surprising therefore that a large number of talented Indian students go to the US year after year.

The US has, unlike any other country in the world, strategically instituted innumerable scholarships, freeships and assistantships to facilitate absorption of several hundred foreign students (the number of Indian students in USA last year was 86,000).

In the context of discussing the quality of university education, the comparable figures in the overall education system between the two countries becomes useful to get a much more comprehensive picture of higher education.

As shown earlier, there appears to be a big gap in terms of quality of university education between India and US but what is more striking is there is also a huge gap in terms of actual numbers when one moves to higher levels of college education. It can be noted that, the enrolment figures of India significantly exceed the US up to the level of the first degree. However, the world famous

Table 7: Comparison of the Education System of India and United States on Key Indicators

Enrolment in Education	India	US
No. enrolled in schools (Gross) (Primary to 10+2 class	195 million +	
Given the drop out rate of 40%, Net enrolment	117 million	75 million*
No. enrolled into colleges (Bachelors and above)	11 million ++	17.4 million *(Includes 10.4 million enrolled into Community Colleges)
No. of universities (most are affiliating; 17600 colleges)	360*	1700
Annual turn-out of Bachelors degree holders	3 million ++	1.3 million
Annual turn-out of Master's degree holders	0.2 million	0.3 million**
Annual turn-out of PhDs	16,500++	45000**

(US sources: *US census Bureau; **NSF) (India sources: + Central statistical organization; ++UGC; * The current number of universities is 426.

graduate schools of the US produce 1.5 times the number of Masters degrees and 2.7 times the number of PhDs in all disciplines compared to India. Interestingly, while US produces far more PhDs in science and engineering (about 1.5 times) compared to those in other disciplines, India does the opposite, i.e. far more PhDs (1.5 times) in other disciplines compared to the number in science and engineering.

However, the comparative picture allows us to conclude,

a) the quality of our educational system at the higher education level, particularly at the Masters and PhD levels have to be significantly higher and, more importantly,

b) this is not an impossible task for India to exceed the US numbers and match their quality in higher education.

MINIMISING INEQUALITY

A more daunting problem threatening India is the stark uneven development of the different regions of the country. There appears to be reasonable recognition by the political leadership regarding the economic as well as social disparities, though these disparities are increasing with time. What seems to be lacking is the absence of recognition of institutional disparities across different regions particularly in higher education. The disparity unfolds itself in terms of actual number of institutions of higher education to the difference in the quality of these higher education institutions in the different regions. Such institutional disparities could indeed be causing economic disparity. For instance, there appears to be a high correlation between enrolment in higher education and per capita GDP of the States of India (Figure 2).

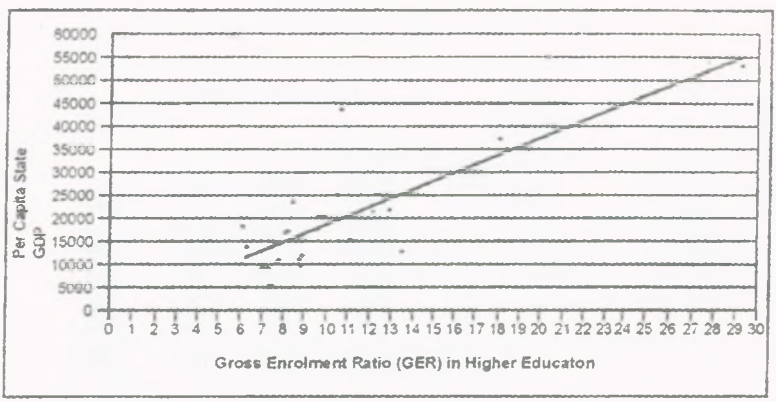


Figure 2: Correlation Between Per Capita State Domestic Product and Gross Enrolment Ratio in Higher education.

Source: Keynote Address by Dr. M. Anandakrishnan at the 36th Annual Meeting (2006) of the Indian Society for Technical Education.

As a case in point, it may be useful to highlight the kind of institutional disparity that is on the rise in India, in the case of engineering education and bio-technology R & D institutions. These two examples are relevant in the context of the spectacular growth in information technology (IT) and bio-technology (BT) seen in India during the recent past.

During the past five years, i.e., between the years 2000 -2006, engineering education in India has witnessed a growth where the annual intake has grown by a factor of 5 to the present level of over 560,000. While this is a remarkable development in higher education, growth in this sector has not occurred evenly in the country. Around 60% of the present intake is accounted for by just four States, namely Andhra Pradesh, Tamilnadu, Karnataka and Maharashtra. The situation is not very different in respect of the other market oriented disciplines like pharmacy, architecture, computer applications and business administration. It is shown in Figure 3 that in all these disciplines, the above 4 states account for 50 –65% of the intake.

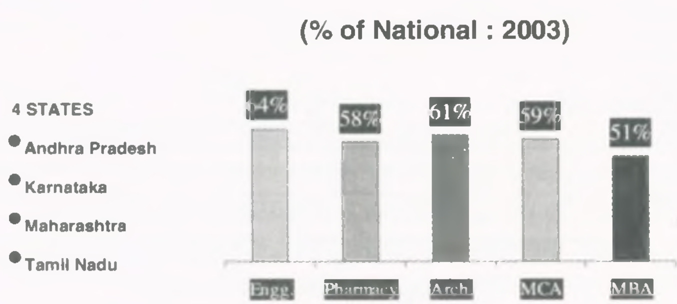


Figure 3 ***Intake at undergraduate level correlated to ITES employment****

*The same four States account for 57% of ITES & BPO employment

Source: N.G. Satish, Administrative Staff College of India as Part of the NIAS Project on Regional and Sectoral Imbalances in the Development of S&T in India

The economic implication of this disparity is evident from the fact that the same four states account for nearly 57% of employment in the IT enabled services and business process outsourcing industries. With the total employment is presently at 1.6 million in these segments, and considering the potential for growth in employment in the coming years, the close correspondence between institutional and employment disparities ominously suggests that, concentrating development of technical skills in only a few States could lead to a major divide in the country. A consequence of such a divide might be migration of population into a few States, such as these four States, in search of technical education and consequently for employment.

The bio-technology R & D institutions trace a different pattern among the states of India. In this case a comparison can be made between two groups of States as has been done in Figure 4. One group consists of Andhra Pradesh, Delhi, Karnataka, Maharashtra

Figure 4 Regional disparity in the biotechnology R&D scene**

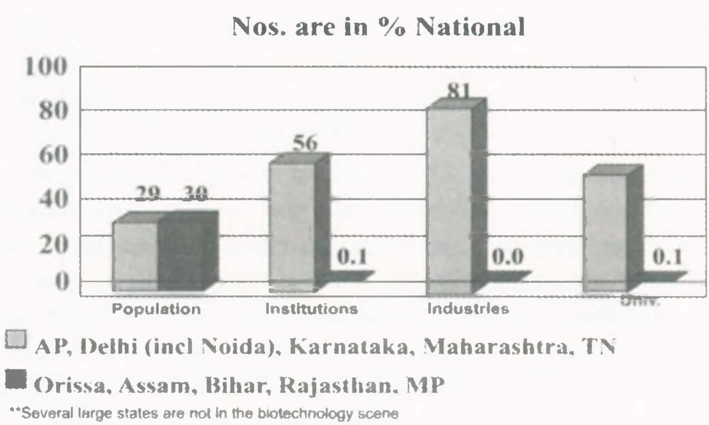


Figure 4 Regional disparity in the biotechnology R&D scene**

Source: N.G. Satish, Administrative Staff College of India as Part of the NIAS Project on Regional and Sectoral Imbalances in the Development of S&T in India and Tamilnadu, while Orissa, Assam, Bihar, Rajasthan and Madhya Pradesh constitutes the second group. Each of these two groups of States accounts for 30% of India's population. The disparity in the strength of bio-technology R &D institutions between these two groups is striking. While the former group has set up and nurtured 50-80% of the R & D institutions, the second group of States do not count for much in this regard.

These examples point out how important it is to analyse asymmetries in the distribution of institutions of higher education as well as of science and technology in the country. National Institute of Advanced Studies (NIAS) has taken up a major project to carry out such an analysis.

INTERNATIONALISATION OF FACULTY AND STUDENTS IN UNIVERSITIES

A key element contributing to the unmatched supremacy of the American universities is that they attract talent from all over the world. They are able to do so because of several unique features associated with the US universities. Besides those discussed earlier in this article, it is noteworthy that world-class universities in the US do not impose a citizenship requirement on their faculty following the dictum of the American Council of Education (ACE) that "academic talent knows no national boundaries". This liberal policy has stood the US education system in good stead.

Although US universities like any other country face, faculty shortages, they have never faced a crisis situation like what India is currently going through. This is primarily because they draw distinguished faculty from different countries. It is same case with regard to student enrolment in higher education. At any given point in time, the United States will have around 60,000 students on their campuses. The US also sends out on an average around 20,000 students to other countries on an annual basis. However, very few of these students come to India.

There are major lessons for India to draw from the US successes in respect of internationalising the faculty and students in universities. The potential benefits from such internationalisation could be immense. Because of the principle that education and research thrive on the basis of universality of knowledge systems, absorbing talented people at the faculty and at the students level from diverse educational and cultural backgrounds would be crucial for a more wholesome academic fellowship(Natalicio,2004). Besides, there could big economic gains.

FUTURE DIRECTIONS FOR HIGHER EDUCATION IN INDIA

Among others, India has to be forward looking and develop a comprehensive strategic plan for the development of science and technology in the country. Of significant importance is to strike the right balance between original research and technological

Table 7. Comparison of Technology Base Index Among Selected Countries.

India's gains in strategic Technology	Technology base index(TBI)*	
Indigenously designed 600-700 MWe PHWRs in 5 years construction time	USA	0.73
INSAT system for TV access to more than 80% of population	Japan	0.70
IRS system for management of national natural resources	S. Korea	0.67
Long range guided missiles	India	0.20
Power plant equipment		

*TBI is a composite index of four criteria:(For details of the calculation please see HDR 2001)

(a) Technology creation (patents and receipts of royalty and license fees from abroad);
(b) Diffusion of recent innovations (ICT and exports of higher and medium technology products);
(c) Diffusion of old innovations (telephones and electricity); and
(d) Human skills (average years of schooling and gross tertiary enrollment in science, maths and engg.).

innovation. There must be a quantum leap in the quality of scientific and technological research in the country. The culture of research needs to permeate our universities that are the essential building blocks and suppliers of trained scientific and technical workforce in the country. Thus, broad basing the trained scientific and technical humanpower in the country has to receive increased focus. This will lead to enhanced knowledge infrastructure. Research in basic sciences must regain its importance and must be the foundation of learning in all universities.

IMPROVING THE QUALITY OF RESEARCH

Original research has taken a backseat in India as a consequence of the market forces. A major reason for this is that the university system has been weakened in the absence of research. The consequences of this can have a far-reaching impact. For instance, the R&D human power in India is only about 0.15 per 1000 (most of whom are in government laboratories) compared to 4 per 1000 in USA and more than 7 per 1000 in Japan. Further, the effect of India's low research across the board is most starkly reflected in India's low technology base index (See Table 7).

The fact that the country has made notable R&D gains in strategic fields is important but not sufficient. Even at this stage, when the government investment in R&D is increasing manifold, the fields of manufacturing and microelectronics, for instance, are lagging far behind (Table 8) in comparison to the rapid strides being made in novel technology areas. There is an urgent need for rejunevating R & D in familiar technology areas as well, in view of their potential of a major impact on the economic well-being of the country.

ENHANCING KNOWLEDGE INFRASTRUCTURE

Infrastructure discourse and comparisons often refer to per capita consumption of electric power and the number of telephones per unit of population, i.e. telephone density. In the same way

Table 8. Developments in Novel Technologies vis-à-vis Lack of Comparable. Progress in Familiar Technologies

Novel technologies

- ***Information Technology (IT)***
  (IT Industry proposes to induct >3,50,000 Engg. Graduates)

- ***Biotechnology (BT)***
  (Pharmaceutical Industry investment in R&D is highest at nearly 5% of turnover)

- ***Nanotechnology (NT) (over Rs.200 crore in 2006)***
  (Master Degree courses and Nano Science Research Centres in increasing nos. of institutions)

vis-à-vis

Familiar Technologies

Manufacturing
Steel Industry
Al, Cu , Zn
Auto components
Aviation
Microelectronics
Instrumentation

(Employment prospects unclear; R&D Investment <0.5% turnover; No New Courses or Research Centres)

one can use doctoral density, that is the number of PhDs per unit of population, as a measure of knowledge infrastructure. The telecom policy aimed at doubling or trebling the telephone density and, with an effective regulatory authority in place, achieved phenomenal expansion, especially in mobile phones, in which there was substantial, commendable private participation. As a result, there are over 100 million mobile phones in India currently.

We need to achieve a similar expansion in the field of research-based degrees.

The number of PhDs produced annually in our country in science and engineering is about 6000 presently. The US, which produces about 27,000 annually is the single largest producer of PhDs in science and engineering in the world. The difference in output of PhDs between US and India is a factor of about 4.5. On the other hand, the per capita consumption of electricity, an index of physical infrastructure, for India is about 600 kwh with the corresponding figure for the US being about 13,000 kwh, which means a difference by a factor of more than 20. India does not have the financial resources to raise the per capita consumption of electricity in our country even by a factor of 4.5 in the near term, let alone closing the gap between India and the US.

On the other hand, the investment that is required to raise the number of PhDs by a factor of 4.5, i.e. to the level of the US, is definitely within the realm of realisation if one works towards it. India can certainly reach the level of the US with regard to the number of PhDs in the near future. It has been noticed that increasing the production of electricity is on the national agenda, although the achievements have been modest. Unfortunately, increasing the number of PhDs, strangely, does not figure in any policy agenda. It is precisely these two sectors, electricity generation and advanced research, that are fundamental to the prosperity of any nation. However, the country is yet to discover the magic potion that will enable it to achieve a quantum leap in the two sectors.

We have in place an impressive institutional framework for higher education with over 370 universities and over 17,600 colleges. A target of 30,000 high quality PhDs, as judged by robust, time-tested processes of evaluation, in science and technology is not beyond the capacity of the institutional strength that we have. It is only that we had not, until recently, set such a goal to be achieved. This is now being sought to be corrected by an MHRD empowered committee headed by Professor M.M. Sharma.

In the past, questions, such as where is the market for PhDs, were raised in chorus. As noted earlier, that situation has changed dramatically. GE, a multinational company, sought 1200 PhDs for its Jack Welch Centre in Bangalore. Although GE has been the forerunner in this area, more and more domestic industries (e.g. BIOCON) as well as foreign industries (e.g. IBM and GM) are offering attractive employment opportunities to PhDs. A major void in India's numerous engineering colleges is the lack of qualified teachers with a Ph.D. If only the regulatory mechanisms were stringent and effective, hundreds of these colleges would have had better-qualified teachers. The experience of research among the teaching faculty is integral to developing a research culture in these institutions of higher learning.

The discussion on PhDs is actually a discussion on research skills. When reference is made to the creative work force, what is connoted is the strength of innovative and research-capable personnel. In this respect, as well as the gap between the US (with a creative workforce of 1,200,000) and India (about 200,000 strong) is again a factor of about 6 and certainly can be bridged. What is the difference between an individual in the creative workforce and one on a factory shop-floor. Peter Drucker, in his classic text entitled "The Age of Discontinuities" brings out the difference by characterising the knowledge worker as one who puts in an "exceptional day's work" as opposed to the manual worker who puts in a "fair day's work". Incidentally, he adds that a fair day's work deserves a "fair day's pay" while an exceptional day's work needs to be rewarded with "exceptional pay". India's public-funded institutions have not been able to reward exceptional performers adequately and action is called for to institutionalise imaginative reward systems.

The reason why the strength of R & D personnel is low in India is because most of them are in government laboratories like those of DRDO, DAE and DOS. The laboratories of these agencies are the best endowed in our county. They have also undertaken highly challenging projects. However, the strength of their staff is substantially inadequate. On the other hand, the 370 universities of India are home to a large population of young researchers. However, their resources and infrastructure are nowhere near what the agency laboratories have. The universities cannot therefore take up grand-challenge projects. There is thus. a mismatch between the human resource they are endowed with and what they can take up by way of R&D. On the other hand, the opposite kind of mismatch characterizes R&D agencies.

The only way to erase these mismatches is to build strong bridges between the university system and the agency laboratories. One way of building such bridges is to set up one or more of agency laboratories with focused R&D programmes on the campuses of academic institutions. A good model to emulate is the Applied Physics Laboratory (APL), largely funded by US defence R&D (DARPA), on the campus of Johns Hopkins University, Baltimore. In India, an outstanding such example is the Central Leather Research Institute (CLRI), a CSIR laboratory, on the campus of Anna University. The organic link between CLRI and the University in which it is located has resulted in the remarkable situation that 65% of leading personnel in the leather industry leaders in our country today are products of the symbiotic connection between CLRI-Madras (then) – Anna (now) University.

Given the growing number of youngsters and the role that they can play in a knowledge-driven economic system, India has to mount a campaign focused on generating a large, highly-trained work force. This is the responsibility of not just the government but also that of the industry.

CONCLUSION

In conclusion, universities in the current scenario will have to gear towards becoming a part of the distributed knowledge production. This essentially will be people and competence-centred.

The key feature will be to strike a balance between competition and collaboration on several levels and different forms. Knowledge production is increasingly a socially distributed process. Its focus is global. The universities must enlarge its view of its role in knowledge production from that of being a monopoly supplier to becoming a partner in both national and international contexts. Such a imperative change will necessitate a redefinition of excellence among academic institutions.

It is increasingly being realized that there is no longer a linear sequential and hierarchical models from research to development to innovation and use. The inter-linkages between the elements of research development innovation and use has several patterns and ways that also crosses several disciplinary boundaries and does not imply the presence of al' these elements in every single model. The thrust for any existing model could be anchored by any one of the above mentioned elements while all the other elements play subsidiary but strategic role in the model.

Though the scientists will remain important in proposing areas of research, research prioritization will be generated through an interface between the various stakeholders and hence will increasingly become participative and broad based. Research in the universities will have a cognitive and social dimension.

Institutions of higher education will have to strike a balance between existing stable and continuous forms of organizations to those that are more flexible, and temporary. The real challenge will be of locating a point on the continuum of rigidity, flexibility and chaos.

An excellent passage from a recent article by Professor R. Radhakrishnan of the University of California is worthy of quoting here:

"60 years ago Nehru declared to the world that India had successfully

kept its tryst with destiny. If that declaration announced the birth of a new nation both to itself and to the world, six decades later India is engineering yet another rebirth as it aligns itself with its own internal pulse and the rhythms of a globalised world economy".

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Quality of Engineering Education

N J RAO

1. PREAMBLE

Engineering education is both the cause and effect of many forces in the society. A fast growing industrial sector generates a need for new technologies, and consequently for engineering manpower that can generate new products for the expanding markets. A well-trained engineering manpower can bring about qualitative changes in the nature of industrial activities in any country. Engineering, more than any other profession, has more direct impact on the wealth creation in any nation. Engineers can help design, install, support, and maintain national infrastructure. They can serve as change agents, not only for technical systems, but also for many other systems of the society. Hence, in a technologically intensive society, the education and training of the technologists and engineers assume a great importance and are treated as basic needs.

Generally, the fundamentals engineers learn in colleges remain fundamental but the way in which these fundamentals are applied changes rapidly. Hence, without integrating the knowledge from various disciplines and applying them in innovative ways, it is difficult for engineers to continue to be effective. The quality of education received by the engineers will have a direct impact on how the companies, where they are employees, compete in and contribute to the global economy. Technological innovation is central to wealth creation and economic growth (*Bordogna*, 1997). Engineers must be enablers to wealth creation rather than simply be a commodity on the global market (ABET, 2002) to sustain a competitive advantage of any nation.

As India moves forward with the ambition of becoming a 'developed country', it is crucial to recognize that an economically strong India can emerge only if it can create competitive technologies and use them to produce wealth. Availability of engineers, technologists and scientists is a prerequisite for this to happen. In the wake of a quantum jump in technologies with global connectivity, coupled with the new liberalized socio-economic revival, the quality of education provided at the undergraduate level is of paramount importance to the Indian economy. This paper identifies the current status of engineering education in India, the current practices of accreditation and their limitations, and proposes an outcome based quality measurement system that attempts to reduce the gap between the needs of the industry and the competencies of students graduating from undergraduate engineering programmes.

2. STATUS OF ENGINEERING EDUCATION IN INDIA

The growth of engineering colleges is shown in the figure 1. As can be seen from the figure, the rate of growth of engineering colleges took a step change in early 90s immediately after

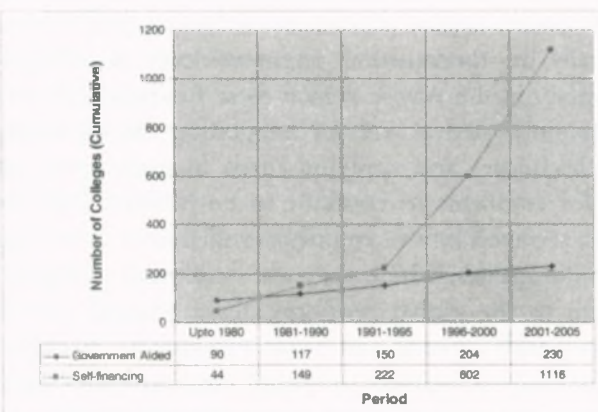

Figure 1. Growth of Undergraduate Engineering Colleges in India

liberalization. As of 2005 India has 1346 degree-level engineering institutions with a student intake of nearly 450,000. Out of these 1346 approved engineering colleges, 1116 fall under the self-financing category (*http://www.aicte.ernet.in*). Institutions providing undergraduate engineering education in India can be classified as follows.

Indian Institutes of Technology (IIT): IITs are country's topmost institutions for engineering education. At present, India has seven IITs located in New Delhi, Mumbai, Kanpur, Kharagpur, Chennai, Guwahati and Roorkee. Student enrolment at these institutes at undergraduate level is limited to about 4000.

National Institutes of Technology (NIT) and Regional Engineering Colleges (REC): Seventeen RECs were established in various States as joint and cooperative enterprises of Central and State Government. Out of seventeen RECs, fifteen RECs have been upgraded to NITs and made deemed universities with direct and enhanced funding from Central Government to provide world-class infrastructure and faculty.

State Government Colleges and University Departments: There is a large network of engineering colleges established and administered by State Governments and Universities. Some of them are more than a century old and have been pioneers in engineering education in the country.

Aided Colleges: These colleges are managed by Private Education Societies. They take up the responsibility of providing capital assets like land, buildings, etc. Government provides salary and other working expenses to these colleges. These institutes are affiliated to one of the universities in the state.

Self-financing Institutions: Self-financing engineering colleges have grown at a very fast pace during the last decade. These institutions start with the approval of the AICTE and get affiliated to one of the Universities (usually a technical university established by the concerned State Government) in the state.

Some features of the current engineering education in India are

- Student intake into engineering programmes is more than 450,000
- Majority of (more than 80%) of engineering graduates come from private institutions
- Nearly 600 self-financing institutions come under three universities.
- AICTE is the statutory body, established for proper planning and coordinated development of technical education system throughout the country.

There are several problems associated with the large technological universities, and they have a direct impact on the quality of learning.

- There is no academic autonomy at the levels of teacher, department and colleges. As any changes have to acceptable to more than hundred institutions, the tendency is to settle for the lowest common denominator.
- There is excessive concentration of power at the university headquarters. This leads to autocratic decisions or inadequate attention to many issues.
- Admissions, examinations, and administration take more time than time for learning.
- Many academic processes including examinations and evaluations get designed to meet the needs of lowest quality students.
- The current practices of evaluation of large number of answer scripts lead to forcing the students to answer questions in a prescribed manner, and in fact penalize the good students who are creative.
- More time and effort goes into preventing malpractices and responding to revaluations, rather than into quality improvement

Many problems got created because of the fast growth of these institutions

- Too many institutions are in their early phases of getting established, and many university related processes get designed to meet their requirements.
- The number of qualified faculty is woefully inadequate. In fact many programmes run with 30 to 40% less faculty than the prescribed strength.
- The relationships among the government, university and managements of private institutions become unhealthy because of many factors including political. The admission processes take politico-legal hues every year, and the casualty is always the time available for learning.

There are additional problems created by the nature of growth of industry, which is the primary user of the engineering graduates.

- Majority of the jobs are in the IT sector, though the requirements for engineers in other sectors have started increasing in the recent past. As majority of IT related jobs do not need knowledge from engineering domains, the students really will have no strong motivation to learn their engineering subjects.
- As the IT sector grows at more than 20%, the need for engineers into this sector is very high. This leads to fast increasing entry level salaries, and that makes the teaching positions unattractive. It becomes difficult to attract even average level graduates into teaching positions, which to begin with are not very attractive.
- An average graduate has possibly four jobs waiting for him after graduation, and this does not encourage his juniors to put in effort to learn his engineering well.
- There is a huge mismatch between the programmes offered at the colleges and needs of the large scale employers of engineering graduates. On top of this there has always been very little interaction between industry and engineering colleges.

- Preparation for good placements and performing well in the examinations appear, at least in view of teachers and students, to be more and more incompatible with learning engineering subjects well.

3. ACCREDITATION OF ENGINEERING PROGRAMMES IN INDIA

National Board of Accreditation (NBA) is charged with the task of evolving a procedure for assessment of quality in the technical education sector in India on the basis of specified guidelines, norms, benchmarks and criteria. NBA aims to recognize and acknowledge the value addition in transforming the admitted raw student into a capable engineer having sound knowledge of fundamentals and acceptable level of professional and personal competence for ready employability in responsible engineering assignments (Manual for NBA Accreditation, 2000).

NBA has defined criteria and standards by which the strengths and weaknesses of individual programmes in an engineering institution can be judged. These are classified into three indices, eight criteria and seventy variables that measure the different aspects of a programme.

1. *Organizational / Infrastructure Performance Indices*
   Criterion 1: Mission, Goals and Organization – 12 variables
   Criterion 2: Financial & Physical Resources and their Utilization - 12 variables)
2. *Academic Performance Indices*
   Criterion 3: Human Resources (Faculty & Staff) – 13 variables
   Criterion 4: Human Resources (Students) – 8 variables
   Criterion 5: Teaching – Learning Processes – 10 variables
   Criterion 6: Supplementary Processes - 5 variables
3. *Industry – Interaction Indices:*
   Criterion 7: Industry – Institution Interaction – 7 variables
   Criterion 8: Research & Development activities – 3 variables

NBA introduced first set of changes with effect from 1-1-2003 (Manual for NBA Accreditation, 2003), and the second set of changes with effect from 1-1-2004 (Revised Manual for Accreditation, 2004). Some additional changes have been made to the scoring sheets of NBA in 2005. Comparisons of the three systems of assessment are presented in tables 3.1 to 3.5. The grading system has changed from 'A, B, and C' classification to 'Accredited for 5 years and 3 years' in the 2003 revision. The minimum requirement for accreditation has increased from 550 points to 650 points in this revision (Table 3.2). Minimum standards (50%) for the 3 critical criteria - HR –Faculty, HR- Students and Teaching Learning Process are introduced in the second revision (Table 3.27). Total number of variables to be assessed is reduced from 70 to 57 in this revision (Table 3.3). More weight is given to the institute level performance than the department level performance (Table 3.4) in the new accreditation process. While the total number of criteria has been kept at eight and the total weight at 1000, the names and weights of individual criteria are modified in this latest revision (Table 3.5).

Table 3.1: Revisions of NBA accreditation processes - Grading system

Accreditation System	*Total Points (Out of1000)*			
	<550	550-650	650-750	>750
Earlier System	Not Actd.	C	B	A
From 1-1- 03	Not Accredited		Accredited for 3 yrs	Accredited for 5 yrs
From 1-1-04	Not Accredited		Accredited for 3 yrs	Accredited for 5 yrs

Table 3.2: Revisions of NBA accreditation processes - Minimum requirements for getting Accreditation

Accreditation System	Total Points required	Points required for Individual Criteria
Earlier System	550	Nil
Modified from 1-1-2003	650	Nil
Modified from 1-1-2004	650	80 for HR–Faculty 50 for HR-Students 175 for Teaching-Learning Process

Table 3.3: Revisions of NBA accreditation processes - Total numbers of variables to be assessed

Accreditation System	Number of variables
Earlier System	70
Modified from 1-1-2003	70
Modified from 1-1-2004	57

Table 3.4: Revisions of NBA accreditation processes - Split up of points among Institute and Department

Accreditation System	Inst. Level	Dept. Level	I / D Level	Total
Earlier System	171	352	477	1000
Modified from 1-1-03	171	352	477	1000
Modified from 1-1-04	249	325	426	1000

Table 3.5: Revisions of NBA accreditation processes - Criteria for Accreditation

Earlier System			*Present System (Modified from 1-1-2004)*		
Criterion Number	Criteria Earlier System	Wts	Criterion Number	Criteria From 1-1-2004 Onwards	Wts
1	Mission, Goals and Organization	100	1	Organization and Governance	80
2	Financial & Physical Resources and their Utilization	100	2	Financial Resources, Allocation and Utilization	70
			3	Physical Resources (Central Facilities)	50
3	Human Resources: Faculty& Staff	200	4	Human Resources: Faculty & Staff	200
4	Human Resources: Students	100	5	Human Resources: Students	100
5	Teaching – Learning Processes	350	6	Teaching – Learning Processes	350
6	Supplementary Processes	50	7	Supplementary Processes	50
7	Industry–Institution interaction	70			
8	Research & Development	30	8	R & D and Interaction Effort	100
Total		1000	Total		1000

A detailed 'principal component analysis' and 'factor analysis' of 200 cases prior to 2004, and 78 cases after 2004 indicates (Viswanthan, 2006) the following.

1. NBA followed an elaborate process by assessing 70 variables of a programme for deciding the accreditation status prior to 2004, but the final decision appears to depend only on the perception of evaluators of the overall performance of the programme. All the criteria scores are significantly different for the 'Accredited' and 'Not-Accredited' programmes. Hence, all of the criteria had the discriminatory power in segregating between the 'Accredited' and 'Not-Accredited' programmes.
2. The award of accreditation status based only on a single summated score does not seem to be a good practice as it gives a provision to compensate the weaknesses in some critical areas with the surplus in some non-critical areas.
3. The revisions in 2004 indicate a positive shift of assessment from resource perspective to process perspective. An attempt to reduce subjectivity from the process is visible.
4. The basic weakness of both NBA processes is the lack of outcome orientation.
5. The distance between the performance variables and the proxy variables used for actual measurement and the inability to account for the interdependence of variables are significant.
6. NBA processes can be further improved through some modifications to the present score sheet of NBA and by modifying the weights given to different criteria.
7. The major limitations require a restructuring of NBA criteria and variables and the development of a new questionnaire for data collection.

The results of detailed statistical analysis indicate clearly it is necessary to design a quality assessment system that is much more outcomes oriented and uses measurements that are more objective.

4. FUNDAMENTAL ISSUES TO BE ADDRESSED

An undergraduate programme is conducted in a given context to meet certain identified needs of the society. There are a number of stakeholders for engineering education who include students, parents, teachers, support-staff, and managements of colleges, industry, and governments. While the interests and concerns of all the stakeholders are not exactly contrary, they are not in desired alignment either. Much of this misalignment is a consequence of not adequately articulating what constitutes engineering education in a continuously changing context. In the absence of such documents created by the regulatory bodies like AICTE, every stakeholder is free to define implicitly or explicitly all aspects (programme outcomes, how curriculum to be designed, what constitutes good engineering, measures of quality etc.) of engineering. This combined with a fast changing economic and consequent social scenario, and the creation of large technological universities leads to a very unsatisfactory state, in which the present engineering education is.

In the opinion of the author, the problem starts with the very word 'engineering'. The spectrum of definitions (collected by the author from hundreds of engineering students, teachers and practitioners) indicates that there is not even a reasonably common understanding of the term. While there are dozens of definitions of the word 'engineering', majority of them are similar, each one emphasizing some specific aspects of engineering. A regulatory body like AICTE should arrive at an operative definition of the word, and communicate strongly to all the stakeholders. Some operative definitions of "engineering" are given in the Appendix.

Any curriculum should be designed to make the graduates of the programme to perform well in the roles they are assigned to. The roles engineers are likely to play during the first five years after their graduation include Product Design and Development, Product Engineering, Custom Engineering, Manufacturing, Installation and Commissioning, and Operation/Maintenance. Other roles engineers are likely to get into, however, after additional formal education, include Education and Training, Marketing/Sales, Management, Entrepreneurship, Development of Technology and Systems, and Research in Engineering Science. The numbers indicate that 90% of engineering graduates opt for the first category of jobs. Unfortunately all the programmes are designed implicitly, for a variety of reasons, to train them for careers in Development of Technology and Systems, and Research in Engineering Sciences. This is not an issue that admits simple compromise or resolution. With a large percentage of students not motivated for these two roles, it leads to indifference and lack of motivation to the courses offered. This issue can technically be resolved through providing streams and electives. But it requires an extensive debate.

Any accreditation process requires references against which the inputs, processes, and outcomes can be compared. The present NBA process identifies such references with respect to only a small number of items like faculty-student ratio, classroom sizes, transportation, books in the library, and hostels. All other variables are left for subjective evaluation.

The most important reference ought to be the statement of "programme objectives" which reflect the needs of the nation at any given point of time. A survey of "programme objectives" of different countries demonstrates the manner in which their national priorities are incorporated. Unfortunately, there is no statement of programme objectives by AICTE. Consequently, the Boards of Studies of engineering programmes have no obligations or references to be met. One suggested list of programme objectives is given in the Appendix.

5. MEASUREMENT OF QUALITY OF ENGINEERING EDUCATION

While inputs and processes are essential components of any programme, the outcomes that result from their successful utilization are much more important. Many innovations are possible and normally do happen to overcome deficiencies in some resources or processes, if there is clarity and concurrence with regard to the expected outcomes. Every stakeholder will be able to understand the impact of any of his/her or others' actions on the outcomes. Besides, the most effective manner in which the nature and quality of a programme can be influenced is through redefining its outcomes. In the opinion of the author, competencies of the graduating students should constitute the main outcomes of a programme.

As per UNIDO competency is 'a set of skills, related knowledge and attributes that allow an individual to perform a task or an activity within a specific function or job'. In the context of education, 'competency' is the ability of a student that enables him to accomplish tasks adequately, to find solutions and to realize them in work situations. Competencies consist of components that are trainable (knowledge, skills) and components that are more difficult to alter (attitudes, beliefs). Competencies can be categorized into ''managerial', 'generic' and 'technical'. Competencies are characterized by 'Competency Title', 'Definition', 'Knowledge Requirements', 'List of competencies at different levels', 'Methods' and 'Tools'.

Competencies serve as the basis for interaction with the industry who is the main consumer of the output of the colleges. Competencies should, therefore, constitute the basis for designing curriculum, creating streams in a programme, and differentiating the programmes.

While competencies can be treated as the main outcomes of a programme, they are the results of very long teaching learning processes, and complex interrelationships among and decision making by all the stakeholders. Any quality measurement system should, therefore, be designed in such a manner that all the stakeholders should be able to relate to its components on a day-to-day basis. Besides, the measurements should not involve very complex and time consuming processes, and should enable regular review and enhancement activities. The quality measurement should be done in a layered manner as different measurements can be done at different time intervals and different stakeholders influence different variables. These layers can be identified as

- Student-teacher interaction
- Department that determines the curriculum, provides facilities, schedules, creates an ambiance that impacts the motivation of students, teachers and support staff, creates and manages alumni network, and determines the industry-department interaction that has influence on placements, projects undertaken, and motivation of students and teachers.
- Institution that provides effective interface with the outside world for students and teachers, creates systems and processes for conducting all its academic activities, facilitates good placements, creates and manages effective interaction with industries and alumni.
- University to which the institution is affiliated.
- Government and other regulatory bodies

Student-Teacher Interaction: This has the greatest and direct influence on the levels of competencies achieved by the students. This is the level at which there is scope for endless number of innovations and also possibilities for failures and frustrations. For this interaction to be effective, it should be autonomous, have checks and balances, have adequate resources, and operate in a nurturing environment. The competency of a student in a given domain is a function of

- the grade obtained by the student
- quality of testing
- quality of evaluation
- the quality of syllabus of the course
- The grade obtained by a student depends on
- quality of instruction
- competencies in the prerequisites
- ability to learn
- willingness to learn

The causal relationships among these variables can be captured diagrammatically as shown in the figure 2.

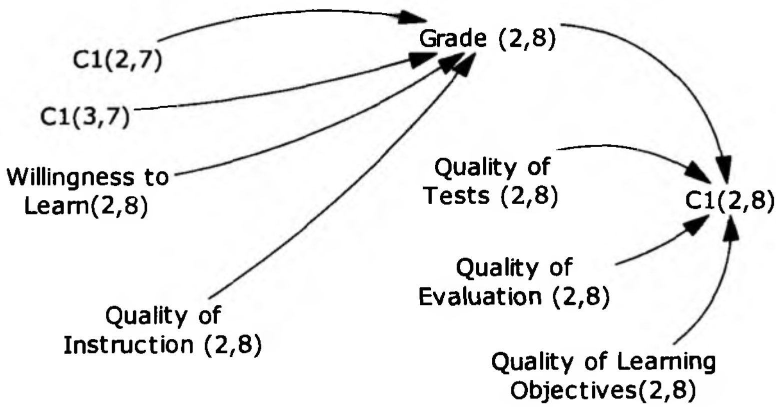

Figure 2. Competency as determined by teacher-student interaction

However, the first semester courses need minor modifications to these causal relationships as shown in the figure 3.

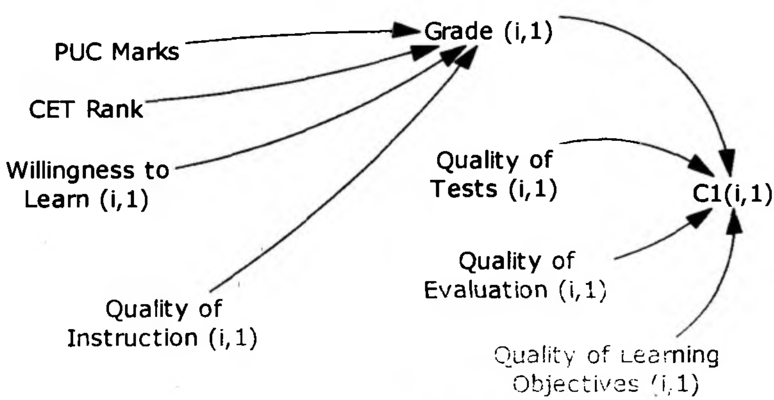

Figure 3. Competency as determined by teacher-student interaction in the first year

It is necessary to develop instruments to measure all these variables and administer them during and at the end of the semester. Once the process is set in motion, the overhead involved in continuous measurement of quality is not significant. The very method of measurement and the scores received by the students and teachers will act as direct feedbacks. When it is implemented all the necessary documentation would automatically get generated, which would also serve the purpose of accreditation eminently.

6. CONCLUSIONS

Engineers are the initiators, facilitators, and implementers of the technological development of a nation. The way engineering education is conducted is important to the future of the nation. Competencies of the graduating students constitute the basis of their placement. A thorough introspection by all the stakeholders is necessary to identify the outcomes of engineering programmes unambiguously. An outcome based accreditation process should be put in place. AICTE should play a key role in facilitating these processes.

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APPENDIX: SOME OPERATIVE DEFINITIONS OF ENGINEERING

Engineering may be defined as "application of objective knowledge to the creation plans, designs and means for meeting the needs of people and society at large". The main task of engineering is to find and deliver optimal solutions to real life technical problems, within the given material, technological, economic, social and environmental constraints through the application of available objective knowledge.

ABET definition of Engineering

"The profession in which a knowledge of the mathematical and natural sciences gained by study, experience, and practice is applied with judgment to develop ways to utilize, economically, the materials and forces of nature for the benefit of mankind"

J. A. L. Waddell, Frank W. Skinner, Wessman (1933): Engineering is the science and art of efficient dealing with materials and forces ... it involves the most economic design and execution ... assuring, when properly performed, the most advantageous combination of accuracy, safety, durability, speed, simplicity, efficiency, and economy possible for the conditions of design and service.

Proposed list of Programme Outcomes

a) An ability to apply knowledge of mathematics, science and engineering to design a system, component or process to meet social needs.
b) An ability to design and conduct experiments and to analyze and interpret data and outcomes.
c) An ability to identify, formulate, model, and optimally solve engineering problems using relevant techniques and engineering tools.
d) An ability to communicate effectively in both oral and written forms.

e) An ability to understand the social, environmental, economic, and ethical impact of engineering activities
f) An ability to carry on learning on an independent and sustainable basis.
g) An ability to function on teams.
h) An ability to implement and organize engineering works systematically under given constraints.

The Technological Challenge in Health Care

M S VALIATHAN

After listening to the two brilliant presentations on Atomic Energy and Space, I wondered why health and education could not claim similar achievements. Health and Education are afterall the sum total of human resource development; yet their performance in free India is a study in contrast with Atomic Energy and Space. This is a cause for great concern.

In coming to my subject which centres on health, it is evident that its opposite is disease and suffering which are the unfailing companions of every society – humans, animals, and plants. Even gods were not spared because the divine physicians – Ashwins – were kept busy all the time! The aim of healthcare, of which medical science is the foundation, is to provide relief if not cure. If there is no disease and no suffering, health care would be hardly needed. How have we in India done in providing health care since independence? In trying to answer this question, I would be drawing upon the observations of the Commission on Macroeconomics and Health which submitted an important report to the Govt. of India in 2005. To begin with, life expectancy which was 32 in 1947 has gone up to 66; infant mortality rate which used to be 150 has dropped to 70; small pox and guinea worm have been eliminated: malaria has been contained; and half a million deaths from TB have been prevented by implementing the 'directly observed treatment'. Tertiary care is available in all the major cities and even in smaller towns. Fifty years ago, General Hospitals used to have large 'fever wards' which were always crowded with patients, most of whom suffering from typhoid fever. I can recall those 'unhappy far-off' days when the mortality in the fever wards used to average 30%. Another major killer was labor pneumonia. Today a medical student hardly sees such patients because typhoid fever and pneumonia are easily treated and often not admitted to hospitals. There has been a revolutionary change for the better. This must be acknowledged.

But the bad news is that we have a list of failures to mar the array of achievements. For example, malnutrition, infant and maternal deaths have stagnated since 1990 even though some states like Kerala and Tamilnadu have done better and scored above the national average. Life expectancy, infant and under–5 mortality in India are worse than those of Bangladesh. Pakistan eradicated small box, guinea worm and polio ahead of us. According to the WHO, India has 16.5% of the global population but contributes 20% of the disease burden of the world. Compounding all this is poverty which has a demonstrable effect on diseases which take a virulent form in undernourished persons especially women and children. In the absence of a social insurance scheme, people are compelled to incur out-of-pocket expenditure for medical care with the result that 3.3% of India's population are driven into bankruptcy every year. The poorest 10% sell their land and assets to meet the cost of treatment. The Swaminathan Commission on farmers noted that 30% suicides among farmers occurred because they had been driven into bankruptcy by the cost of medical treatment of family members. Poverty aggravates illness which in turn drives people into penury. This is the vicious cycle which characterises the life of millions of Indians. The Commission's report has given disturbing forecasts as well. While communicable diseases, especially water-borne, will continue to decline, HIV/AIDS will rise to three times the present level: tuberculosis, claiming 8.5 million, will increase in association with HIV/AIDS; prenatal and child mortality may not decline; lastly, the millennium goals in health set for 2015 may not be achieved on time. This is not all.

Human society goes through what is known as epidemiological transition in the evolution of public health. The pre-transition phase is characterised by short life expectancy, epidemics and the high prevalence of communicable diseases. As nutrition, sanitation and housing improve and life expectancy rises, communicable diseases fade away and noncommunicable diseases such as heart disease and cancer become the major killers. India has entered the post-transition phase but communicable diseases have not disappeared. We have therefore the double burden of pretransition and post transition diseases. It is reported that cancer incidence will increase 25% and mental health problems affecting 6.5% of the population will increase further due to rapid changes in the socio-economic domain. The Kerala experience is a case in point. Kerala's health indices are comparable to those of developed countries and have been hailed in India and abroad. But Kerala's suicide rate is three times that of the national average. Obviously high scores in public health do not necessarily mean that the society consists of happy people or they are at peace with themselves.

In the development of health case programmes, many different groups are involved and their contributions are as important as they are not interchangeable. Consider the following list:

Physicians

Physicians represent the frontline, who are charged with the care of patients and responsible for carrying out procedures for diagnosis, treatment and prophylaxis. There is no health care programme where the physician does not play a vital role.

Scientists:

Scientists are called upon to identify the cause of diseases; investigate the reemergence of old diseases or emergence of new ones; find remedies and prophylaxis for ailments and many other tasks, which call for contributions from biology, pharmacology, chemistry, immunology, biomedical engineering and other disciplines.

Sociologists:

How do the health care policies and programmes impact on the society? The progress in health care expenditure or laboratory tests may fail to tell the whole story. I would give an example. Rheumatic heart disease is common in India especially among women and the poor. When the disease damages the mitral valve and narrows its orifice, the valve is opened surgically by an operation called mitral valvotomy. The operation is straightforward and gives good relief to patients who are able to live normal lives again. Thanks to echocardiography, one can measure the orifice size of the valve before and after the operation and make sure that the valve was opened satisfactorily. Suppose a woman whose valve was opened satisfactorily according to echocardiography is found by a social worker to be sitting at home and not allowed to work because she is a 'heart patient'; to be turned down by prospective bridegrooms or abandoned by the husbands: should that be called a successful operation? Societal audit is important in many other situations too.

Technologists:

The role of technologists will be dealt with later in detail as that is the burden of my lecture.

Managers and administrators:

It is not often appreciated that poor management is responsible for many of our failures in the health sector. What do you make of a State with a population of 30 million presiding over 45000 employees and 1500 vehicles in its Directorate of Health Services, spending several hundred crores a year and witnessing the decay of its Taluk and District Hospitals which are thoroughly unfit to take care of patients? The severe mismatch between inputs and outputs is obviously caused by skewed management which can and should be rectified. The large investments made by the state in the health care system will not give satisfactory returns unless good managers and administrators are inducted and empowered to bring about reforms.

Politicians:

Politicians decide ultimately on how much to invest in the health sector. It is well known that the allocation for health in India declined after the Third Plan, and currently averages less than 1% of GDP, which is less than that of several countries in sub-Saharan Africa. Moreover health is a state subject in India and national policies are implemented by states which vary widely in efficiency and commitment. This is reflected in the sharp geographical disparities in health among the different states in India.

Industry:

The CII estimates that the Indian health sector as a whole would amount to 100,000 crores a year in five years. This is a mind boggling sum and indicates the significant role of the health sector in the national economy. The major role of industry in the manufacture of goods and equipment, operation of services and so on in the health sector is self-evident.

I have listed the important stake holders in our health sector but shall confine my discussion to technology for health care before this audience. Technology is a basket term which means all things to all men. To illustrate its role in transforming health care, I will give a specific example. Coronary artery disease was not a common medical problem in 1956 when I qualified as a doctor in Trivandrum. If a patient with effort angina came to our hospital we would then take a careful history, do a 'physical' and carry out routine laboratory examination of blood and urine. This would be followed by chest x-ray and electrocardiogram. He would then be treated with nitrates for angina and digitalis for signs of cardiac failure. He would also receive plenty of advice on 'taking it easy'. This was all we could do in those far-off days and the patients expected little else. What is the situation today? History and physical would of course be done as before but they would be followed by a battery of biochemical tests in a multi-channel analysers. Two dimensional echocardiography would demonstrate the patient's heart chambers, valve motion, wall thickness and other features; a stress test with thallium is a must and, if positive for ischaemic changes, would be followed by coronary angiography and, nowadays, 64 – slice CT with digital subtraction angiography. If all these tests show significant narrowing of the coronary arteries, a balloon angioplasty would be done in suitable cases and coronary artery bypass in others on or off a heart-lung machine. If he has chest pain and the coronary arteries are unsuitable for balloon angioplasty or bypass, he could benefit from Tran myocardial laser revascularization – a procedure pioneered by Prof. Sen. of Mumbai many years ago as 'snake heart operation'. Finally, if the heart muscle is largely replaced by scar tissue as a result of repeated 'heart attacks' and the patient has 'end-stage heart disease', a heart transplant would be recommended. The management of coronary artery disease was revolutionised in 50 years and the changes were invariably brought about by advances in technology. For convenience, technology in the healthcare can be grouped as follows:

* Instruments	(analytical, electro-physiological, optical, and imaging for diagnosis; Lasers, linear accelerators, lithotripter etc. for treatment)
* Devices	(Disposables and Implants; Prosthetics such as dentures and limb Prostheses).
* Biotechnology products	- Diagnostics (HIV kit)
	- Therapeutics (human insulin)
	- Vaccine (HIV vaccine under trial)
	- Tissue-engineered organs (under development)

* Space technology and IT	-	Telemedicine
	-	Computerised Medical records
	-	V R in medical and allied health training
* Nanotechnology	-	Nanowires, cantilevers used as probes in biological systems for molecular imaging
	-	Nanoparticles for drug delivery

The groups above demonstrate clearly that virtually every branch of science and technology has contributed to the advancement of health care. Technologies are needed at all levels of health care – primary, secondary and tertiary – but the level of complexity increases progressively from the primary to the tertiary level. A thermometer, disposable glove or syringe would be needed at the primary health centre whereas a CT or MRI would be called for in the tertiary referral Centre. The market for the range of technologies for healthcare in India is estimated to be 1.3 billion US dollars against 79 billion in the US; and 2.5 in China. In terms of per capita use of medical technology, the figure for India is US dollar 1 against 47 for Singapore, 16 for Brazil and 79 for Israel.

What is noteworthy is that while India imports 45% of the total requirement for medical technologies, the percentage rises to 95% in the high technology segment. India's manufacture is confined largely to low end items such as gloves, syringes and so on. There is hardly any export of high end technologies. So long as this state of affairs continues, there is little hope that the benefits of modern medicine will reach the common man because the high import content of medical care will make it too expensive. In view of the gravity of the problem, the Indian National Science Academy appointed a Committee under Dr. Sikka's chairmanship to study the status of instrumentation in India as the dependence on import is not confined to medical instrumentation. The Sikka Committee found that India's innovation record in instrumentation is poor as indicated by the figures for patents – 3 US patents for India in 2003 against 5000 for US and 900 for Japan. India published no more than 32 papers in 2000–2003 in the Review of Scientific Instruments, which again points to the lack of interest in the development of instruments. Apart from this, the excellent experience of Space, DAE and DRDO has had little impact on energising the instrumentation industry in India. In listing other inhibiting factors, the Committee noted the poor interaction between academic and industry and the back of a global vision in industry. Industry felt that Indian scientists tended to develop non–patented instruments by reverse engineering which was of little interest to them, Indian R&D took too long and the Indian product was not user-friendly. Furthermore, there is no component industry with the result that spare parts must be imported and in the absence of spare parts, major equipment is shut down for long periods. When instrument prototypes are developed by M.Tech. candidates, they seldom undergo validation, acquire IPR or enter commercial production.

Since India became a signatory of WTO, MNCs can set up R&D laboratories and wholly owned subsidiaries in India without Indian partners. Their target is the middle class of India - estimated at 200 million - who can afford to purchase modern health care, which is an attractive market for them but which leaves out the bulk of the Indian population. MNCs are represented in developing countries by sales agents and as many of us have found to our cost, their after sales service is poor. Besides they raise the price of equipment by 70% for sale in the developing countries as noted in an editorial in Nature two or three years ago. They have little interest in the transfer of technology as they have freedom of operation after WTA came into effect. When MNCs set up R&D laboratories and employ hundreds of Indian PhDs, the IPRs arising from their labour belong to the company, and do not add to the indigenous knowledge capital. If things go on in this manner and advanced health care becomes available to a small percentage of Indians and the rest are denied the benefits, the consequence will be a disastrous polarisation in our society. The warnings are audible with the rise of popular sentiment against 'five star hospitals'.

The Sikka Committee recommended several measures in an effort to remedy the grave, if not hopeless, situation. These included the mandatory participation of academia and industry in all R&D projects on instrumentation; technology parks in close proximity to R&D institutions; not insisting on large up-front payment and rigid conditions which a nascent industry can hardly hope to meet; setting up an instrumentation development fund to promote the exhibition of Indian instruments abroad; tax credits to industry which exploit Indian innovations successfully; creating a website with a national data base on scientists and technologists with their area of expertise for the benefit of industry; organizing component and subsystem parks in collaboration with MNCs and so on. Most importantly, the Sikka Committee recommended a mission mode approach to produce medical instruments on the model of the auto parts Mission of the Government because of its enormous social importance, sharp focus and a market of over Rs.6000 crores a year. The Mission mode is essential to cut across the barriers between Ministries, States, private sector and, if necessary, even MNCs. There is no reason why the Mission should not succeed globally and give India a leadership position is at least one branch of instrumentation - analytical, electrophysiological, optical etc.

While R&D and production are the job of the scientists, technologists and industry, regulation is the responsibility of the Government. Here the Government dithered for two decades when India had no legislation to cover medical instruments and devices. When faced with the approval of marketing for a blood bag and other devices including implants, the practice of the Health Ministry was to refer them to the Drug Controller General of India even through DCGI's office has no expertise whatsoever to evaluate instruments and devices which involve electronics, computer science, material science and biomedical engineering. After twenty years and several Committees later, the Government have notified a Indian Medical Devices Regulatory Authority (IMDRA) which will apparently function under the DGHS and regulate the medical application of instruments and devices. The notification does not have the authority of a legislation which is still pending.

I have talked about technology which represents one wheel of the chariot of medicine. The other wheel is compassion which is another subject, for another day.

Programmes for students and teachers – the Science Education initiatives of Indian Academy of Sciences

N MUKUNDA

1) My sincere thanks to Prof. B V Sreekantan, Dr K Kasturirangan and Prof. Bhuvan Chandel for inviting me to speak at this National Seminar. I will present some ideas and describe some efforts of the Indian Academy of Sciences in trying to improve science education at college and university levels in India.

2) The subject 'University Education in Science' was considered in depth by a Committee set up by the Academy in 1994, and a paper was issued by Academy Council in December that year. Some of the comments and suggestions made there seem to have been noticed particularly by various Committees concerned with science education in recent years. I would like to recall a few points from the paper, to reinforce points you would certainly be familiar with.

   a) The ability to absorb, transfer and create new technology can be achieved only against a background of solid foundations in the basic sciences.
   b) Our institutions and educational system should simultaneously provide two things: opportunities for a small number of highly talented students who can go on to research careers in science; and for a much larger number of students good quality training in science for practical

careers outside of research.

c) Science at the college level should be solid and broad based, and should avoid specialising too early into job-oriented courses. These can be available later, otherwise the students' conceptual foundations would remain weak. After core courses common to all streams are covered, flexible combinations of subjects should be permitted and encouraged - Quoting from the paper:

"...... breadth and flexibility have to be key features of an educational system that expects to attract and retain gifted young people."

d) Integrated MSc as well as Integrated Ph.D. programmes – after school and after college respectively – should be created in our good institutions; and at least in a few places undergraduate teaching in science should take place along with MSc level and active research, as in a university setting.

This paper of the Academy has been referred to in a Report prepared in 2004 by a Committee set up by the Scientific Advisory Committee to the Cabinet to "examine and recommend new Science Education initiatives from 10+2 onwards". The Report was presented and discussed in detail at a day-long seminar held at IIT-Delhi on 31 March 2005, inaugurated by President Kalam. A major recommendation is to set up high quality institutions combining undergraduate teaching and research in science, built around a core Integrated MSc programme. This idea has been taken quite seriously, and it seems that to begin with two such new institutions will soon be established.

In December 2004, at the invitation of the Planning Commission, the Academy had made many specific proposals for improvement of science education at colleges and universities. Advice was obtained from UGC Vice Chairman as well as from Scientific Secretary in the Office of the Principal Scientific Advisor to the Government, in drafting these proposals. I mention this here only because of the presence of so many senior persons, who may be able to help in these matters. There has been no response so far to the Academy from the Planning Commission. Among the recommendations made I may mention – aid to colleges and universities on a selective basis to improve laboratories used for teaching; institution of scholarships at both undergraduate and MSc levels in good numbers to reach out to students in all parts of the country; and involvement of all the Science Academies of the country in these efforts as well as support to them for their science education activities.

3) Lastly I turn to a description of what the Academy has attempted to do on its own over the past few years. In the 1994 paper it was stated:

"....Academy considers that there is a need to find ways in which it can help identify and reach out to the gifted, save as many of them as possible for the pursuit of science, and make them feel that it is still worthwhile and deeply rewarding to fashion careers in science."

However much we may criticise the present situation in science education – and the pages of Current Science are full of it – we have to deal with our own presently available teachers and students, and surely among them there are many with talent and motivation. With that in mind, the Academy set up a Science Education Panel in 1998 to create and coordinate useful programmes both for students and for teachers. In all these the main contribution from the Academy is intellectual, coming from its Fellowship which is about 870 strong. I would now like to describe these programmes, giving numbers to convey an idea of the scale of the effort.

a) Summer Research Fellowships These are for both students and teachers to work with Fellows for a two-month period.

Presently the Academy gives about 200 Fellowships to students and 50 to teachers each year. The programme started on a very modest scale in 1995, and has slowly grown to its present level. The number of applications received is in the 3000-3200 range. The Table shows also cumulative totals: so far about 850 students and 250 teachers have benefited. The quality and motivation levels of those selected have been very high.

SUMMER RESEARCH FELLOWSHIPS

No. of applications received				No. offered			No. availed		
Year	Students	Teachers	Total	Students	Teachers	Total	Students	Teachers	Total
1995	5	-	5	3	-	3	3	-	3
1996	-	-	-	12	-	12	12	-	12
1997	-	-	-	31	7	38	31	7	38
1998	-	-	-	34	8	42	34	8	42
1999	84	23	107	57	14	71	57	14	71
2000	486	68	554	76	25	101	76	25	101
2001	609	119	728	104	30	134	104	30	134
2002	969	120	1089	107	43	150	107	43	150
2003	1260	152	1412	116	39	155	101	37	138
2004	1689	152	1841	167	37	204	152	36	188
2005	2988	175	3163	202	44	246	180	43	223
Cumulative totals:						857	243	1100	

b) Refresher Courses for Teachers These are of two week duration, and are not tied in any way to requirements for promotion. May be as a result, we have had participants who are highly motivated, and in their 30's and 40's so that they have several years left of active teaching; in turn, by improved teaching skills, we hope large numbers of students will benefit.

So far a total of about 43 courses have been held, starting in December 1999. The numbers in different areas are:

Mathematics – 9, Theoretical Physics – 5, Experimental Physics –

7, Chemistry – 5, Life Sciences – 11, Earth Sciences – 6. These courses have been held in different institutions all over the country, and the participants in each one have been selected on an all-India basis. The planning and conduct of these courses are done by Fellows, with help from others whenever needed. Problem solving, tutorials and discussion sessions are integral parts of these courses. Some details of all courses organised are in the next four tables. The number of participants is usually around 25, sometimes a bit lower and sometimes in mathematics as high as 40 or 50.

The 7 Experimental Physics courses have been particularly well planned and run, and a manual is being written for wide circulation.

REFRESHER COURSES

Cumulative totals:	Mathematics	Theoretical	Experimental Physics	Chemistry Physics	Life Sciences	Earth Sciences
	9	5	7	5	11	6

Sl. No.	Subject	Venue	Dates	Fellows involved	No. of partici-pants	Amounts spent (Rs. in Lakhs)
1.	Mathematics	Panjab University, Chandigarh	Dec. 99	I.B.S. Passi R. Bhatia D. Prasad	44	1.49
2.	Life Sciences	Karnatak University Dharwad	June 2000	K. Saidapur R. Gadagkar	22	2.25
3.	Life Sciences	IICB, Kolkata	Nov. 2000	Samir Bhattacharyya	25	2.25
4.	Theoretical Physics	Bishop Moore College, Mavelikara, Kerala	Nov. 2000	S. Chaturvedi R. Simon N. Mukunda	28	1.70
5.	Life Sciences	Univ. of Mysore, Mysore	Sept.-10-22	H.A. Ranganath R. Gadagkar	28	2.65
6.	Experimental Physics	Goa University, Goa	Oct. 29 - Nov. 12 2001	K.R. Rao R. Srinivasan	18	3.21
7.	Theoretical Physics	Univ. of Hyderabad, Hyderabad	Nov. 18-30 2001	S.Chaturvedi R. Simon N.Mukunda	20	1.23
8.	Mathematics	Harish-Chandra Res. Inst., Allahabad	Dec.3-152001	I.B.S. Passi R. Bhatia D. Prasad	50	2.64

9.	Mathematics	C.M.S. College Kottayam	Dec. 10-21	G. Misra Alladi Sitaram	35	1.77
10.	Theoretical Physics	St. Stephen's College, Delhi	Oct.1-15 2002	S.R. Choudhury N. MukundaR. Ramaswamy*et al*	23	1.35
11.	Experimental Physics	Indira Gandhi Centre for Atomic Research, Kalpakkam	Oct. 18-31	C.S. Sundar Baldev Raj et al	22	3.70
12.	Spectroscopy,	Viswa-Bharati, Santiniketan and S.N. Bose Centre, Kolkatta	Nov. 21–Dec. 7 2002	S. Dattagupta Ranjit Biswas Kankan Bhattacharya*Et al*	14	1.64
13.	Immunology	Interdisciplinary School of Health Sciences University of Pune, Pune	Nov. 25–Dec. 7, 2002	Sudha Gangal M.G. Deo	20	2.91
14.	Coding Theory, Cryptography and Discrete Mathematics	Panjab University, Chandigarh	Dec. 2–14, 2002	Madhu Raka R.J. Hans-Gill R.L. Karandikar *et al*	32	1.98
15.	Physics of Earthquakes	Tezpur University Assam	Dec. 2–21 2002	V.K. Gaur S.N. Bhattacharya S.K. Nath *et al*	31	2.66
16.	Reproductive Biology	Karnatak University Dharwad	Dec. 9–23 2002	S.K. Saidapur S.P Modak A.J. Rao *et al*	10	1.12
17.	Molecular Genetics	Madurai Kamaraj University, Madurai	Jan. 27–Feb. 10 2003	R. Jayaraman V. Nagaraja D.N. Rao M. Hussain Munavar *et al*	18	3.02
18.	Quantum Chemistry	University of Hyderabad	Feb. 16 – Mar. 2 2003	E.D. Jemmis T.P. Radhakrishnan Kalidas Sen S.R. Gadre *et al*	25	1.81
19.	Molecular and Developmental Genetics	Banaras Hindu University, Varanasi	2-14 July 2003	S.C. Lakhotia R. Raman J.K. Roy *et al*	15	2.75
20.	Probability, Statistics and Stochastic	S.N. Bose National Centre for Basic Sciences, Kolkatta	4-22 Aug. 2003	S. Dattagupta K.B. Sinha Probal Chaudhuri *et al*	5	0.72
21.	Experimental	Goa University, Goa	28 Oct– 10 Nov. 2003	R. Srinivasan	13	3.16
22.	Earth Sciences	Jawaharlal Nehru Technological University, Hyderabad	3–15 Nov. 2003	U. Aswatha-narayana K.V. Subbarao	13	1.85
23.	Experimental Physics	Saurashtra University, Rajkot	3–16 Nov. 2003	M.K. Mehta	24	3.30
24.	Physics of the Atmosphere and the Ocean	CAOS, Indian Institute of Science, Bangalore	1–12 Dec. 2003	B.N. Goswami	31	1.67
25.	Mathematics	Berhampur University, Berhampur	1–13 Dec. 2003	V. Kannan	30	2.20
26.	Frontiers in Inorganic Chemistry	Indian Institute of Technology, Kanpur	18–31 Dec. 2003	R.N. Mukherjee S. Sarkar P.K. Bharadwaj	23	1.49

27.	Lasers and applications in Chemical Processes	University of Madras Chennai	19–31 Jan. 2004	P. Natarajan	13	2.05
28.	Experimental Physics	Bhavnagar University, Bhavnagar	25 Oct.–7 Nov. 2004	M.K. Mehta	14	3.78
29.	Experimental Physics	University of Mysore, Manasagangotri	1–15, Nov. 2004	R. Srinivasan	16	2.92
30.	Plant Genetic	Madurai Kamaraj University	7-21 Dec., 2004	K. Veluthambi	23	3.59
31.	Animal Behaviour	Madurai Kamaraj University	8-21 Dec.	G. Marimuthu	22	3.00
32.	Developmental Biology	IISc, Bangalore	14-20 Dec. 2004	V. Nanjundiah	7	2.51
33.	Photonics and materials	University of Madras	13-25 Feb. 2004	P Ramamurthy	19	2.65
34.	Instructional workshop on cryptology	Cochin Univ. of Sci. and Tech. Cochin	2-14 May 2005	S. Ramasubramanian, A. Vijayakumar	39	2.38
35.	Experimental Physics	IIT, Guwahati	9-22 May 2005	M.K. Chaudhuri A. Srinivasan	10	2.92
36.	Foundations of mechanics for senior school students	Central mechanical engineering research institute, Durgapur	16-21 May 2005	Amitabha Ghosh Gopal P. Sinha	150	1.62
37.	Interdisciplinary approaches in biology	Centre for Cellular and Molecular Biology	25 May – 8 june 2005	Somdatta Sinha	27	4.54
38.	Earth system Science	IAS, Bangalore	25 June – 6 july 2005	V. Rajamani S.K. Tandon	19	2.34
39.	Theoretical Physics	SB College, Changanassery	19-30 Sept. 2005	S. Chaturvedi	28	2.55
40.	Mathematics – Probability stochastic processes and applications	Cochin Univ. of Science and Technology, Kochi	Sep. 26 – 7 Oct. 2005	M.K. Ghosh A. Krishnamoorthy	38	3.40
41.	Foundation course in physics and chemistry of the earth	Univ. of Allahabad	Nov. 7–27, 2005	Alok K Gupta	13	2.75
42.	Physics of the atmosphere	Bangalore University IIsc	Nov. 14-25 2005	B.N. Goswami	38	2.25
43.	Applied stochastic Processes	Indian Statistical Institute, New Delhi	Dec. 5–17 2005	S. Ramasubramanian R.L. Karandikar	20	2.75

c) Lecture Workshops These are meant for both students and teachers, mainly at MSc and research level but sometimes at +2 and college level. The duration is 2 to 3 days, again planned and conducted by Fellows. Again starting in late 1999, we have conducted 51 such workshops so far – Mathematics 6, Physics 11, Chemistry

15, Life Sciences 19. From the transparencies you can see how large the audiences often are: 200 or even 400 in some cases, especially in Life Sciences. This has been a very successful programme, and many Workshops have been held in institutions in smaller towns like Davangere, Dharwar, Amritsar, Kottayam, Gorakhpur, Trichy, Coimbatore, Baroda, Mysore to name a few.

LECTURE WORKSHOPS

Cumulative totals:	Mathematics	Theoretical Physics	Experimental Physics	Chemistry	Life Sciences
	06		11	15	19

Sl.	Subject	Venue	Dates	Fellows involved	No. of Partici-pants
1.	Mathematics	B.M. Birla ScienceCentre. Hyderabad	Oct. 99	A. Sitaram	75
2	Mathematics	RRI., Bangalore	Dec. 99	A. Sitaram	110
3.	Chemistry	St. Stephens College, Delhi	Feb 2000	N. Sathyamurthy	100
4.	Life Sciences	Davangere	Mar 2000	V. Nagaraja	140
5.	Chemistry	Univ. of Delhi, Delhi	Nov 2000	N. Sathyamurthy	120
6.	Life Sciences	Abasaheb Garware College, Pune	Aug 2001	J. Gowrishankar	80
7.	Life Sciences	Karnatak Univ., Dharwar	Aug.17, 18 2001	V. Nagaraja D.N. Rao	150
8.	Physics	St. Xavier's College, Mumbai	Sept. 15, 2001		
9.	Chemistry	Guru Nanak Dev Univ., Amritsar	Oct. 29,30. 2001	N. Sathyamurthy R.N. Mukherjee Y.D.Vankar	
10.	Ecology and Conservation	Mangalore Univ., Mangalore	Dec. 7- 8, 2001	Uma Shaanker K.N. Ganeshaiah	90
11.	Life Sciences	St. Xavier's College, Mumbai	Jan . 12, 2002	A.K. Lala Veronica F. Rodrigues V. Sitaramam	100
12.	Theoretical Physics	CMS College, Kottayam	Jan. 14-16 2002	Arup K.Raychaudhuri Diptiman Sen	87
13.	Quantum Chemical calculations and their uses in teaching	St. Joseph's College, Irinjalakuda	18-20Feb. 2002	K.L. Sebastian Manoj Mishra	72.
14.	Chemistry	Gorakhpur University, Gorakhpur	23–24 Nov. 2002	R.P. Rastogi N.B. Singh N. Sathyamurthy	100
15.	Mathematics/ Statistics	St. Joseph's College,Irinjalakuda	4–6 Dec. 2002	G. Misra A. Sitaram S. Ramasubramanian *et al*	65
16.	Organic Synthetic Methods	The American College, Madurai	13–14 Dec. 2002	S. Chandrasekaran Uday Maitra M. Periasamy *et al*	160

17.	Chemistry beyond tomorrow	St. Xavier's College, Mumbai	21 Jan. 2003	J.P. Mittal N. Periasamy	120
18.	Frontier lectures in biology	Univ. of Mysore, Manasagangotri	20-22 Feb. 2003	H.A. Ranganath V. Nagaraja*et al*	175
19.	Current trends Mathematics	Madras Christian College, Chennai	21-22 Feb. 2003	V.S. Sunder R. Ramasubramanian*et al*	80
20.	Theory and applications of statistics	St. Thomas College, Pala	1–3 Oct. 2003	A.P. Gore S.A. Paranjpe S. Ramasubramanian*et al*	100
21.	Nonlinear dynamics and its applications	A.V.V.M. Sri Pushpam College, Poondi	9–11 Oct. 2003	M. Lakshmanan V. Balakrishnan	140
22.	Frontier lectures in Biology	University of Mysore, Mysore	5–6 Nov. 2003	G. Padmanaban M.R.N. Murthy J. Nagaraju *et al*	250
23.	Frontiers in chemical Sciences	Sri Sathya Sai Institute of Higher Learning Prasanthi, Nilayam	10–12 Nov. 2003	S. Chandrasekaran P. Natarajan B.G. Maiyaet al	63
24.	Life Sciences	Auroras Degree College, Hyderabad	21–22 Nov. 2003	C. Mohan Rao Lalji Singh J. Gowrishankar*et ali*	300
25.	Biological Sciences	St. Xavier's College, Mumbai	12-13 Jan. 2004	Sheela Donde	150
26.	Quantum Information Theory	St. Berchmans College, Changanassery	26–28 Jan. 2004	N. Mukunda R. Simon	30
27.	Current concepts in biological Research	Bharathidasan University, Tiruchirappalli	27-28 Feb. 2004	D. Chatterji S. Mahadevan Umesh Varshney D.N. Rao	171
28.	Quantum field theory	Mar Thoma College, Tiruvalla	9-11 Nov. 2004	Diptiman Sen G. Rajasekaran Romesh K. Kaul	80
29.	Solid state physics and quantum mechanics	BCM College, Kottayam	18–19 Nov. 2004	K.L. Sebastian S. Ramasesha P.K. Das K. Babu Joseph	124
30.	Modern Biology	Aurora Degree College, Hyderabad	29-30 Dec. 2004	Ch. Mohan Rao	250
31.	Evolution	Mangalore University, Mangalagangotri	7-8 Jan. 2005 2005	S.K. Saidapur Rajashekhar Patil	85
32.	Molecular biology and microbial genetics	PSG College of Arts & Science, Coimbatore	Jan. 28-29 2005	R. Selvakumaran S. Mahadevan	400
33.	Recent trends in modern biology	S.V. University, Tirupati	31 Jan-1 Feb. 2005	V. NagarajaSathyavelu K Reddy	120
34.	Analysis, probability and Statistics	Raman Research Institute, Bangalore	4-6 Feb. 2005 2005	G. Misra A. Sitaram S. Ramasubramanian	100
35.	Quantum	CMS College, Kottayam	7-9 Feb.	K.L. Sebastian	

	Chemical Computations		2005	Babu Joseph Varughese George	20
36.	Frontier lectures in biology	GSS College, Belgaum	17-19 Feb. 2005	S.K. Saidapur	40
37.	Chemical Theories and Applications	Gauhati Univerity	19-21, Feb. 2005	P.K. Chattaraj	153
38.	Spectroscopy and its Applications	Kongunadu Arts and Science College, Coimbatore	26-27. Feb. 2005	S. Umapathy	250
39.	Frontiers in chemistry:A lecture Programme	Madurai Kamaraj University	9-11 March 2005	R. Ramaraj	145
40.	Microscopic techniques in biology	University of Pune	9-11 March 2005	R.A. Bhisey Deepti Deobagkar	120
41.	Quantum computers	Jawaharlal Nehru University, New Delhi	10-15 March . 2005	Deepak Kumar	35
42..	Chemistry fir Society-Reactions to reality	Sri Sathya Sai Inst. of Higher Learning Prasanthinilayam	24-26 Sept. 2005	P. Natarajan Chelli Janardhana	108
43.	Molecular endocrino;ogy & gamete biology	Daulat Ram College, New Delhi	3-4 Oct. 2005	K. Muralidhar	59
44.	Molecular biology 'Facets and prospects	MS Univ. of Baroda,Vadodara	10-11 Oct 2005	Veronica F Rodrigues	220
45.	Frontiers in biotechnology	CMS College, Kottayam	14-15 Oct. 2005	K.Veluthambi	172
46.	Einstein's legacy	St. Pious X Degree and PG Colege Hyderabad	28-29 Oct. 2005	N. Mukunda R. Simon R. Jagannathan	177
47.	Experimental Physics	Maharani Lakshmi Ammanni College for Women, Bangalore	4-5 Nov.	R. Srinivasan	37
48.	Modern Chemistry and biology	Aurora's Degree College, Hyderabad	28-29 Nov. 2005	T.P. Radhakrishnan	177
49.	Fundamental & Advance aspects in spectroscopy	St. Joseph's College, Irinjalakuda	14-15 Feb. 2006	S. Umapathy	110
50.	Frontiers of Physics	St. Philomena's College, Mysore	17-18 Feb.. 2006	H.A. Ranganath	200
51.	Education and outreach workshop for physics teachers	Indian Institute of Science, Bangalore	10-11 March 2006	Rohini Godbole	22

d) Teacher invitees at Academy meetings This has been a feature for the last ten years. We try to invite upto about 50 teachers as guests of the Academy to attend the Mid-year and Annual Meetings each year. They listen to the scientific and public lectures, meet and interact with one another and with Fellows in their own disciplines; and probably most importantly discuss their common difficulties in a sympathetic atmosphere. So far we have had about 250 teachers in the Mid-Year Meetings, and 400 in the Annual Meetings.

Year	Mid-Year	Annual
1996	16	27
1997	19	31
1998	9	39
1999	23	32
2000	15	34
2001	22	27
2002	25	32
2003	38	32
2004	44	50
2005	33	90
Cumulative totals:	244	394

e) Lastly I mention briefly that since January 1996 the Academy has been publishing a journal devoted to science education titled 'Resonance'. It is a monthly and has completed ten years of existence. I hope at least some of you have seen it – it has a quite attractive appearance, contents of good – may be sometimes demanding – quality, and each issue highlights the life and achievements of a chosen scientist.

CONCLUSION:

I hope I have succeeded in conveying to you what the Indian Academy of Sciences has tried to contribute – both by way of ideas and specific programmes – in the field of science education in the country. All this has of course been possible only thanks to the wisdom of the Council, help of the Fellowship, and unstinted support of the Academy staff.

The Impact of the Genomic Revolution on Medicine

T S SRIDHAR

> We must never cease from exploration. And the end of all our exploring will be to arrive where we began and to know the place for the first time
>
> T.S. Eliot

Keeping in mind the overall goal of this series of talks, I will focus on the impact of the genomic revolution on medicine in general, with special reference to health care in India. I will start with a description of the sequencing endeavour itself, briefly mention the technical advances that have made the simultaneous molecular analyses of thousands of biological components commonplace, and then illustrate the impact of these methods on a deadly disease, chronic myeloid leukaemia. I will then tell you something about what I believe will be the most significant changes to the practice of medicine in the short term arising from the genomic revolution; the ability to sub-stratify seemingly similar patients. I will end by sharing with you clinical problems I have encountered in our recent work, the solution of which would benefit enormously by the application of these methods. Before I plunge in, I want to acknowledge certain concerns that stem from our unique situation of being a scientifically developed nation within an economically developing nation. What will this accomplish for our country? People may very legitimately say "Look, India's goal of improved health for all can only be achieved by providing modern sanitation, clean drinking water, adequate nutrition and, vaccination against childhood viral and bacterial infections. If we ensure that these four things are done well, the health of our people is going to be served better than by our attempts to understand the molecular underpinnings of disease". I have no arguments against this position. In fact there are good data from Scandinavia that support this position. Over the last century, the average life expectancy in Sweden increased by about 25 years; from 52-56 years to 75-81 years. Of this total, 18 years had already been added by the end of the Second World War, a period during which there were no significant advances in drug therapy or cardiac surgery; but significant improvements in hygiene, nutrition, and general living-working conditions. The second half century increased that number by a further 7-8 years, and much of this can be attributed to advances in clinical medicine and newer effective drugs. My stance is going to be, that while the bulk of our public funds should be used to ensure the delivery of the above mentioned amenities, in addition we need to pursue fundamental and applied research into the molecular bases of health and disease. I hope to persuade you of the need and advantages of setting aside a small part of our funds to examine and exploit the opportunities arising from the new technologies.

I want to start with a cautionary note. The lay press has popularized the myth that there is a "gene" coding for every complex human trait, and the gene in of itself determines behaviour. This gross simplification and genetic determinism is quite ridiculous. As Prof. Sharat Chandra speaking before me said, there is no absolute genetic determination, save the monogenic disorders like Huntington's. All other manifestations of health and disease are caused by exceedingly complex interaction between genes and the environment including culture. So please be exceedingly sceptical of newspaper reports that prophecy the end of human stupidity since the gene for "intelligence" has been identified or cloned. There rarely, if ever is any such simple one-to-one relationship.

The sequencing of the human genome has been compared to the landing of humans on the moon. I would be the first one to agree that it is in fact a technical tour de force; in addition the sequence reveals certain facts that have profound philosophical implications. However, I would like to stress upon the aspect of continuity that underlies most modern research and progress in our understanding of the molecular basis of life. The origins of efforts to understand the physical basis of life can be traced through the work and thoughts of many eminent people. A representative modern list would include amongst many others Darwin, Mendel, Garrod- the first person to link an inherited condition to a specific metabolic defect,- Watson and Crick and finally Sanger who made sequencing possible. Craig Venter's pioneering shotgun sequencing was in a sense enabled by standing on the shoulders of these giants

The sequence was published with great fanfare in early 2000, and I urge you to take a look at the interesting images on the covers of the two leading journals *Nature* and *Science*. By this time, the genome of the worm Caenorhabditis elegans, less than a thousand cells large, had been sequenced and was shown to have about 18000 genes. The genome of Drosophila melonagasta, the fruit fly, which is a favourite model system of biologists, had also been sequenced and shown to have approximately 14,000 genes. And what about the Human genome (with a capital H)? 22000. Preposterous! How could it be possible that the lowly worm has 18,000 and we, the most complex being on earth, or so we believe, have only 22,000? I think it is food for thought.

The sequence also revealed that the DNA sequence of two different individuals varies at approximately no more than one in a thousand base pairs. Secondly, the DNA sequence of our closest relative the chimpanzee differs from ours by approximately 1%. These two facts lead to two profound philosophical messages. This is not merely for medicine, but I think for all of mankind. First, much of our cherished notions of regional or religious superiority are mostly rooted in cultural history rather than blue blood pedigree, a sentiment well echoed by the Sanskrit aphorism; "*vasudaiva kutumbakam*". This translates roughly into "All of earth is one family". Second, our anthropo-supremacy is tenuous at best, and in the continuum of primates, the chimp is far closer to us than we would like to acknowledge. It is in this sense that the impact of the sequence is Copernican.

There have been a number of metaphors used to describe the complete sequence of the human genome, the most pervasive being the "blue print of life". I strongly disagree with this metaphor for it conveys an entirely erroneous impression. The word "blueprint" suggests a scaled diagram or plan with all the interconnections implied in the details. It also suggests that using the plan one can put together a working model, or at least understand its function. Most emphatically the sequence is not a plan or wiring diagram. The sequence is a linear array of 3 billion letters of the genetic alphabet. Since, we now understand the code and the punctuations we know that there are 22000 genes specified in the sequence. Hence, a better metaphor might be "list of parts" of a complex machine. Imagine for a moment you have been given the parts list of a Boeing 747 and a full scale working model. It is a daunting list running into tens of thousands of unique parts. No one in their right minds would for a moment believe that the list in of itself would permit the reconstruction of the working model.

So for the younger people in the audience, I want to reiterate that the parts list is merely the beginning. And glorified terms such as "functional genomics" are neologisms for age old activities of biochemistry, cell biology and physiology. There is a whole lot of work to be done for each of these genes before we understand their functions in a normal person, and then its relevance for disease. And in this I cannot adequately emphasise the primary role of research on model organisms.

For the non-biologists in this audience, here is a 30 second primer on the principles of molecular biology. In all freely living organisms genetic material exists in the form of DNA. The central dogma of molecular biology as enunciated by Sir Francis Crick, states that "DNA makes RNA makes Protein". For the most part, proteins are the building blocks as well as the enzymatic machinery of the cell. The implication of the central dogma is that information flow is unidirectional with the DNA guiding the making of RNA as a messenger which then permits the building of specific proteins. There are wrinkles to this, which are not important for the thrust of this narrative.

Now a word about nomenclature. A recent phenomenon is the proliferation of terms that end with 'ome' – genome, proteome, metabolome, transcriptome, you-name-it-ome. People have taken pre existing words and added 'ome' to them, and the resulting term signifies the whole set of all such elements. So in classical "genetics", you studied one gene at a time, and in genomics, you study many or all of the 22,000 genes. On a lighter note, I would tell my American friends that 'ome' is a term they had stolen from us. That it is a very profound ancient Indian term; which was being attached to all brute force science to sanctify it.

I will now move on to the connection between disease and genome. I remember a very interesting seminar when I was a graduate student by Paul Berg, one of the Nobel laureates responsible for the genetic engineering revolution. He said, "I am going to make a provocative statement. I am going to say all disease is genetic". What you have to quibble over is the relative contributions of the gene versus the environment in the causation of disease.

A clinical vignette will illustrate this point. A 40 year-old person notices he is feeling more tired than usual. He also is thirsty often and has increased urination. The doctor examines him and tests his blood and urine for glucose and detects glucose in the urine and a higher than normal level of glucose in blood, confirming the diagnosis of diabetes. Prior to the onset of these symptoms the man had gradually gained 15 kgs over a five year period. His mother is a diabetic as is his elder sister. The doctor offers the patient two alternatives. The first is daily oral medication to control the blood glucose levels, or alternately a regime of controlled diet and moderate exercise but no medications. This person takes the latter approach and loses 10 kilos over the next year and on repeat testing does not have glucose in the urine or elevated blood glucose. Surprise! The disease has disappeared! How could this be? In this case it was the environmental factor of consuming more calories than he used, with the resulting weight gain that precipitated the clinical situation. Loss of the gained weight reversed the condition. Obviously the clinical condition arose because the environmental insult was superimposed on an inherited genetic susceptibility.

I am not going to talk about the monogenic disorders – because Prof. Sharat Chandra has covered that in his talk– but will focus mostly on the complex disease, cancer, and make the argument that we need to participate in this genomic medical revolution in India because it has consequences for the health of our society. Twenty years ago, we had a debate – I remember it was led by Prof. Balasubramaniam, who was at the CCMB at that time – as to whether we should participate in the sequencing of the human genome or not. As a young PhD student I was excessively vociferous in my opposition to it. I said it was merely a technical challenge but anti-intellectual; and as an academic institution we should not participate in the sequencing of the human genome. We would join the party to decipher the biology after the sequence became available.

Now the time has come to decipher the biology. I will add another note of caution. There is a huge chasm between understanding the molecular underpinnings of disease and being able to find remedies for its rectification. Most people agree that sickle-cell anaemia was one of the first if not the first disease to be defined in terms of the fundamental molecular alteration. Ingram at MRC Cambridge determined that a single amino acid replacement in the b chain of the haemoglobin molecule is responsible for all the manifestations of that complex disease. That paper was published in Nature in 1956. It is 50 years hence. We do not have gene therapy for sickle cell anaemia. We do not have drug therapy for sickle cell anaemia. All we have for the treatment of sickle cell anaemia are palliative supportive measures. So knowledge of the genetic and molecular bases and therapeutic amelioration are very far apart. And it is hubris coupled with feeble mindedness to believe that the path forward is short and straight, and ten years down the line, medicine is going to be very different, and everything is going to be decoded and fixed.

The many technical developments in the past thirty years that have enabled large scale molecular analyses have two recurring themes. One is markedly improved resolution and the second is the ability to analyze thousands of components simultaneously. However, I feel that we lag behind in our ability to fully comprehend this ocean of information. This to a certain extent reflects the make-up of biologists; most of the biologists I have known are adept at description and pattern recognition, but when it comes to quantitative analysis, both our training and temperament leave us rather ill-equipped. Co-operative cross disciplinary approaches termed "systems biology" seems to be the way forward.

There have been at least half a dozen revolutionary technologies including production of monoclonal antibodies, sequencing of DNA, cloning of DNA fragments from mammals, the polymerase chain reaction, DNA microarrays and mass spectrometry of proteins. However in the interests of brevity and to support this narrative I will briefly introduce the three techniques that permit rapid analysis of the three critical cellular entities alluded to in the central dogma; DNA, RNA and Protein. These are 1) automated sequencing of DNA, 2) Microarrays to examine messenger RNA expression within a cell and 3) 2-Dimensional separation of Proteins followed by mass spectrometry. Think of these as the legs of a stool, all of which are needed to make sense of the workings of a living cell.

Automated sequencing of DNA has been around for at least 15 years. However a critical step forward which enabled the industrial scale sequencing necessitated by the human genome project was the commercial production of the Prism 3700 by PE Biosystems. I was fortunate to be at Wash U in St. Louis, which was one of the four genome sequencing centres. I remember the excitement in the summer of 1998 in Waterston's lab. This brute had 96 capillaries which could be loaded simultaneously and in a 3-4 hour run each lane could read at least 500 bases. It was the first breaking of the 100 thousand base-pairs a day barrier by a single machine. For biologists it had an impact at least as large as the breaking of the 4 minute-mile barrier had on athletes.

The second technology is micro-arrays that permit the analysis of global gene expression. There are now methods to spot fragments of all of the 22,000 unique human genes on a single glass slide measuring 3 X 1 inch. The messenger RNA from a tissue can be isolated and labelled with a fluorescent tag and added to the slide. Subsequent washing removes everything but the specific pairing of DNA fragments and mRNA. The slide is then scanned by a fluorescent reader. A positive signal at the location of the spot of a particular gene indicates that it is being expressed. It is essentially a snap shot of the activity of the genes in a cell. The typical number of expressed genes in any individual cell type is about 10,000 or half of all the genes in the genome. Imagine now, a situation in which two people with the same type of cancer differ in their response to a drug. The tumor in one patient shrinks and disappears while it continues to grow in the other. One can hypothesize that while the vast majority of genes expressed in both tumors are identical, a small set varies between the two. If tiny bits of the tumor are removed prior to the initiation of treatment, using the micro array and other similar techniques it is now possible to identify these differentially expressed genes. Imagine the advantages if this information were available to a doctor prior to the initiation of therapy.

The third technology is the simultaneous analysis of thousands of proteins by a combination of chromatography (separation) and mass spectrometry (finer printing of fragments). The peptide fragments are compared to the known sequence of thousands of previously characterized proteins contained in a database, permitting the identification of all moderately abundant proteins in the sample. These then are the 3 legs of the stool and a combination of these three technologies has fuelled the study of disease at the molecular level.

I will now tell you the story of the progress in our understanding and treatment of Chronic Myeloid Leukemia. This is a cancer of the white blood cells, a group of cells involved in defending the body against infectious agents. Left untreated the disease kills the patient. In 1960 Hungerford working at U Penn in Philadelphia noticed that one of the chromosomes. number 22 in particular, was shorter than usual in white blood cells from people with chronic myeloid leukaemia. This marker cytogenetic abnormality was termed the Philadelphia chromosome. A dozen years later Janet Rowley identified this change to be a translocation. A translocation is an event, where part of one chromosome breaks off and is attached to another chromosome. This was a case of balanced translocation between the chromosomes 9 and 22. A dozen years later, by which time cloning and sequencing of stretches of mammalian DNA had become routine, the molecular alterations brought about by this genetic shuffling were determined. It turns out that there are two important genes – BCR on chromosome 22 and ABL on chromosome 9. These are genes critical for the regulation of cell proliferation. By breaking and juxtaposing them, a chimera is created, and this chimeric entity has a different structure and is uncontrolled and promiscuous in its activity. As a consequence it leads to increased cellular proliferation. Further progress was made by the pharmaceutical company Novartis where scientists discovered a chemical compound capable of blocking the enzymatic activity of this chimeric protein at doses that did not affect the normal protein. Clinical testing of this drug produced remission of the leukaemia, and the drug is currently sold under the trade name Gleevec. This is one of the more note-worthy instances of rational drug design enabled by knowledge of the molecular genetic alterations. This is the sort of fairy tale all of us who study disease and its genetic basis hope for. However, you have sickle cell anaemia to balance wild hope with stark reality.

I would now like to introduce the idea of disease heterogeneity and the need for patient sub-stratification. In using a specific diagnostic term such as Diabetes or Breast cancer, the goal is to group entities with similar clinical behaviour and response to treatment. However, as we all know, people with identical diagnosis and treatments have very different outcomes. Obviously this kind of lumping hides as much as it reveals. Modern genomic approaches offer a wedge to pry open this door. It is the path to what is often grandiosely termed "personalized medicine". I will try to communicate these ideas by narrating a clinical encounter and the reaction of a famous evolutionary biologist on being handed the dreaded "death sentence" of terminal cancer.

If you can look into the seeds of time,
And say which grain will grow
And which will not,
Speak then to me!

Shakespeare, Macbeth, 1623

In my clinical practice, when I have the mortification of conveying to a patient a diagnosis with dismal prognosis, which by the way as a neurologist happens often, the scenario runs somewhat like this. You sit the patient down and say, "I am sorry to inform you that you have a condition for which there is no proven cure. However, the situation is far from hopeless. You have come in early, and it is possible to do things which will ensure that the progress of the disease can be slowed down and ensure that you retain all your faculties." The next question almost invariably is, "Doc, can you honestly tell me what is really going to happen to ME". And you say, "Well, let me tell you about a systematic study of the largest series of patients with this diagnosis from the Mayo, and they followed a thousand patients over ten years, and ninety percent of the patients made it past five years without any significant morbidity". The next question un-stated most often is, "Doctor, would it be possible for you tell, into which of the groups I fall?" And the sense of helplessness I feel is something I can't really express in words. One shrugs one's shoulders and, I guess, in a resigned way, only to oneself, says, "I can tell you only after five years into which group you fall".

And there is a fascinating tale I read as a medical student in the now defunct Illustrated weekly of India by Stephen Jay Gould a Professor of zoology at Harvard and a gifted populariser of science. Gould then in his forties had been diagnosed with a very rare form of cancer called mesothelioma. This is a deadly cancer of the cells lining the outside of the lung. The damning statistic given to him was that the median survival post-diagnosis was eight months. Translated into English this means that fifty percent of the people with a diagnosis of mesothelioma die within eight months – information to push most people into deep depression.

But Gould did not accept these facts at face value. Those were the days before the Internet and the ability to pull out all published literature with a few key strokes using Google. He supposedly went to the Harvard medical school library and requested the librarian to pull out every article ever published on mesothelioma. After reading through the lot he realised that the curve was skewed to the left but had a long tail. This meant that while the majority died within a year, a small number survived for many years. He managed to identify at least a dozen variables that had an impact on survival. For example non-smokers had greater longevity compared to smokers. I don't know all of those variables. To his great relief he recognised that for most of those variables he belonged to the favourable group. He is said to have remarked, "I won't die within 8 months, but will live for another ten years". He in fact lived for 20 years post-diagnosis. Using gene expression patterns it is starting to become possible to identify these widely divergent clinical behaviours at the outset.

Lastly, I will give you examples of problems unique to our country where we may need to use these genomic approaches to tackle them. For the past 2 years we have been working on identifying molecular markers of drug responsiveness and prognosis in breast and colorectal cancer in Indian patients. When I finished medicine in 1985, breast cancer was largely a disease of post-menopausal in women. The way I remember it is, at least seven if not eight out of ten patients I saw were post-menopausal. Many surgeons I spoke to recently, report encountering a greater proportion of pre-menopausal women with more aggressive disease in their practice in recent years. However, we could not find statistical data from any centre that supported this impression. In a study we have initiated across 18 centres in India, our initial data, mostly from Bangalore and Madurai, indicate that there is a noticeable increase in the 40-45 age group confirming the impressions of most surgeons. I would be the first to agree that these numbers are very small, and the study needs to be extended significantly. However, this pattern has not been reported in the West and hence it is "our problem". We need to determine if these younger women have the same sort of disease as the older group or if there are molecular differences that affect their response to treatment and outcomes.

There is an additional aspect of the nature of breast cancer in India that is different. Breast cancers have been categorized as being estrogen-receptor positive or estrogen-receptor negative. And this is very important because if a patient is estrogen-receptor positive, you use anti-estrogens for that patient and thereby decrease the proliferation of cancerous cells. In Western cohorts 75 to 80 percent are estrogen-receptor positive. There was a report from the Tata Memorial Hospital in the nineties, which had mentioned that the proportion of breast cancer patients whose tumor has detectable levels of the estrogen-receptor in our population was less, much less. In fact they had said that it was lesser than 40 percent. And sure enough, we found very similar proportions in our cohorts. If you look at the annual age-adjusted incidence of breast cancer over last 25 years in the US, the incidence is going up, but the cancers tend to be estrogen-receptor positive. Interestingly, simultaneously the estrogen-receptor negative breast cancer has actually come down in the US. So the very type that is actually going down in the US cohort is going up in the Indian cohort. And more importantly it is happening in younger women who are pre-menopausal. Now, if WE don't study this problem, I know for a fact that the Western pharmaceutical industry is not interested in estrogen-receptor negative disease because they don't have a drug, and that's just the way the pharmaceutical industry operates. It is in our interest to follow this and try to get to its roots, and then hopefully find a way of halting it.

There is one another practical issue that dictates our need to become adept at the use of these genomic approaches to study diseases. It is to apply these methods to diseases that affect our population to the exclusion of the West, for example malaria and leprosy. There were only 13 new drugs developed for all tropical diseases in the last 25 years. Pharmaceutical companies are largely discontinuing their research into these problems unless there are significant numbers affected in the West. They see it as a low return on investment. It is naïve to expect solutions either from the Western pharmaceutical industry or public funded research for these types of problems.

I would like to end by suggesting that the way forward is to promote the availability of information about these advances of modern biology and their implications for public health. We need to encourage and foster healthy discussion of the implications; for many of these issues are complex and the choices are far from straight forward. Finally we should hope that in the long run prudence and wisdom prevail instead of hype and hysteria.

Role of Scientist in Relation to Society

S S KUMAR

Science and Technology, as widely recognised, is the foundation on which rests the welfare and progress of Society. Unfortunately, the spirit of this recognition is dampened by the passive role which Scientists and Technologists are playing in awakening the society to confront challenges which threaten its very survival. This is a matter of serious concern which I intend to share with you in the hope that, at least, some of you may give it a serious thought and devise methods to address these concerns in the interest of societal welfare.

Ladies and gentleman, firstly, we must realize that natural forces (God) has laboured hard for millions of years before the humans could be evolved or created. This is evident from the history of the earth, which itself is 4,600 million years old. During the first 1100 million years of its age, the environment was very harsh and not suitable/permissive for any kind of life to arise or exist. This is testified by the discovery of the oldest fossil structures which are 3,500 million years old. The first eukaryotic cell (a cell with essential traits of the cells of vast majority of the living organisms) is recorded to be 2,100 million years old. The multicellular algae (found in sea water now) are estimated to be 1,000 million years old. The earliest land plants, (which first invaded the land) arose nearly 440 million years ago.

When traced backwards, the history of man seems to have begun nearly 4-5 million years ago. Our remotest ancestors (*Australopithecus afarensis*) existed nearly 4 – 2.7 million years back and after having passed through various evolutionary stages (*Australopithecus africanus* – 3-2 million year ago; *Australopithecus robustus* – 2.2 – 1.6 million years ago; *Homo habilis* – 2.4 – 1.5

million years back; *Homo erectus* 1.8 – 0.3 million years ago; *Homo spapiens archaic* – 500-200 thousand years ago; *Homo sapiens neandertalensis* – 150 – 35 thousand years ago) culminated in the evolution of *Homo sapiens sapiens* 1,20,000 years ago with no compassion in killing his enemies, but instinctively providing care to the elderly and sick.

You will realize that, compared to the age of the earth and other organisms, humans came into existence only about 2 million years ago. They evolved into the sole species (*Homo sapiens* nearly 500,000 years ago), whose descendents are surviving to-day. Inspite of being so young on the time-scale of their origin, *Homo sapiens* alone were blessed with the intellectual capacity to understand and solve problems. This trait enabled them to become the masters of other organisms.

Since the earth came into existence, there have been five major mass extinctions i.e. the first nearly 439 million years ago (during Ordovician-Silurian); the second nearly 364 million years ago (during late Devonian); the third about 251 million years ago (during Permian-Triassic); the fourth nearly 214 million years ago (during late Triassic); and the fifth about 65 million years ago (during Cretaceous-Tertiary). Of these five mass extinctions, the third was the worst in which 95% of all species living then perished.

These five mass extinctions were natural events probably resulting from volcanic eruptions, glaciation, global climatic alterations, and changes in oxygen & salinity levels in oceans and above all meteoric impacts and comet showers (the exact causes still unclear). Luckily, the humans had not evolved by then. Now having evolved, the man, in complete disregard of God (natural forces), HIS creation and even global concerns, has taken upon himself (engaged) the task of (in) causing imbalance in the environment and hasten next (6^{th}) mass extinction. What a great contribution the man is making for the welfare of the society!

Be as this may, there is no controversy in the final analysis that God (natural evolutionary forces) created men/women which can be clubbed under any one the following four blood groups that are determined by the type of glycoproteins on the red blood cells.

Blood Type A: Red blood cells possess A - type glycoproteins
Blood Type B: Red blood cells possess B- type glycoproteins
Blood Type A B: Red blood cells possess both A – type and B – type glycoproteins
Blood Type O: Red blood cells lack these glycoproteins

These blood types hold true for the entire human population and that religion, caste and creed, and geographic distribution of human population has no bearing, whatsoever, on these blood types. Since the blood type is a constant/stable character, it remains the chief guiding factor in inferring the real phylogenetic (God made/nature evolved) relationship in human population.

In this regard, the medical effects of blood transfusion (given in books – Table-1) provide unequivocal proof of the true relationships in the human population.

Table 1. Medical effects of blood transfusions

Donor Type	Recipient Type	Effect onRecipient	Permissible Blood Donation?
A	A	-	Yes
	B	Clumping	No
	AB	-	Yes
	O	Clumping	No
B	A	Clumping	No
	B	-	Yes
	AB	-	Yes
	O	Clumping	No
AB	A	Clumping	No
	B	Clumping	No
	AB	-	Yes
	O	Clumping	No
O(Universaldonor)	A	-	Yes
	B	-	Yes
	AB	-	Yes
	O	-	Yes

It is obvious that when the recipient refuses to accept the blood of donor in transfusion, it cannot have a close natural (God created) relationship with the donor. However, if the blood of the donor and the blood of the recipient are compatible during transfusion, then the donor and the recipient have indeed a close natural (God created) relationship. Any other relationship (based on religion, caste, creed, geography, politics), sought to be made by religious leaders and politicians (in their lust for power), is a mere exploitation of the human population and a shameless defiance of the GOD'S (natural evolutionary forces) WILL.

Is it not a matter of great concern that HIS creation (man) is cheating the creator (God), while pretending to be HIS worshiper? He is making nations/religions/people fight with other nations/ religions and pushing people of the same blood group to kill their own kind.

Did humans inherit this cruelty trait from their ancestors? Undoubtedly, our supposed ancestors, the Chimpanzees, displayed aggressive behaviour so as to protect themselves from their enemies. The evolution of the descendents of humans (man) was accompanied by the evolution of enormous brain size, capacity to think, reason and show controlled behaviour, in contrast to the instinctive behaviour of his ancestors who lived 500,000 years back. In his aggressive behaviour, the man has rather humbled even his ancestors. Is it not shameful, that we have adopted the concept of nuclear families so as to escape from the care of our elderly and infirm people, ignoring the fact that our remote ancestors, inspite of their animal traits, were taking care of their aged and sick elders?.

Should it not be a matter of great concern that the scientists, expected to be seekers and practitioners of truth, are not speaking against the evil of religious, caste and geographic divide of man?. Is this silence of scientists designed/adopted to promote their careers or is it that they fear a danger to their lives from politicians, religious leaders and preachers of hatred? There is a need for introspection by the scientists, followed by a corrective action to save the society from slipping back to the instinctive trait of aggressive animal behaviour of our ancestors.

How unfortunate it is, that the highest evolved creation of God, the man, is engaged in destroying all forms of HIS creation! Recall to your mind the dreadful event in human history, when Hiroshima and Nagasaki were destroyed by the Americans through the use of Atom bomb. In this destruction, the living envied the dead. Is it not baffling, that inspite of a large army of scientists in the United States, there were only a few who protested against assembling of this weapon of mass destruction ! That no lesson is learnt from this human tragedy is evident from the fact that, in the garb of self defense, some nations have added far more dangerous and destructive weapons to their arsenals. It is rather sad that the scientists are willingly obeying their political masters to enable them to win the race of supremacy. In this endeavour, is the society not being pushed to sit on the mouth of a volcano?. If the scientists failed to raise their voice against the destructive strategy of nations at this juncture, the history will not pardon them.

Further, the scientists also have a definite role in cleaning the society from some evils. However, it is a matter of shame, regret and concern that some scientists, blinded by their ambition to rise to higher positions (Vice-Chancellors, Professors, Eminent Scientists), are belittling science by indulging in plagiarism. Still worse are those men in authority, who (for reasons best known to them) rescue these plagiarists. Where is their conscience? What is the society doing to save itself from this kind of degradation?

These questions would agitate every righteous mind, but there is no solution except to bring about a change in the mind-set of the people without which all technological advances are rendered meaningless, because it is ultimately the man who will operate the machine in the way he likes.

Another matter of concern for the society is the depleting biodiversity. The plants that you see around are the product of nearly 420 million years of evolution. These are indeed the precious gift of God (evolutionary forces) for supporting all forms of animal life (including man) and also ensuring environmental balance.

The man is not sparing even this creation of God (nature). A visit to the Himalayas, Nilgiris and Western Ghats would reveal the manner in which the forest floors are being scrubbed to destroy all vegetation (mostly carpet-forming lower plants and some small-sized flowering plants too). This human activity is rendering the forest floors naked. There is a little realization that during torrential rains in the Himalayas and other mountains, the water runs down the slopes at terrific speed. So, if the forest floors are rendered naked, the speeding water will erode the soil along with the mineral content of the eroded soil. Not only that, even the roots of the trees and other higher plants will also get exposed. As it continues, the trees will be uprooted. The tiny lower plants, which carpet the forest floors, not only prevent soil erosion by absorbing water (which is sometimes 20 times of their own weight) and minerals therein, but also serve as nurseries for the germination of seeds of higher plants. Additionally, these plants also support lower forms of animal life and facilitate reproduction in birds whose nests are chiefly (about 90%) made of these light-weighted lower plants.

Unfortunately, the foresters are not taking any steps to save the forests floors. The government is also not moved. The famous botanists are used to looking only at the flowering plants. They do not bend to look at the forest floor. Thus, they are unable to realize the damage that scrubbing of forest floors is causing.

In this manner, we are loosing biodiversity at all levels. We are loosing it at chromosome level, gene level, species level, generic level, family level, ecosystem level, forest level and at aquatic level. Just imagine the loss - every day about ten species are being wiped out from the surface of the earth. It is also estimated, that during the first ten years of the present century, this rate of loss will rise to 25 species per day. With this speed, how much time will it take before the entire plant wealth goes down the drain and no biodiversity is left? While we loudly cry over the loss of biodiversity, we do practically little to preserve it.

Ladies and gentlemen, further imagine that if this destruction of biodiversity were to continue, the Himalayas which are nearly

60 million years old, the Western Ghats and the Nilgiris which are far older would be a in a pitiable condition. Imagine the effect of this situation on society and nature. How mindless we are? The highest creation of God (the man) was given the brain to command the earth and environment, but look at the way he is commanding? The self-centered man is unmindful of the fact that he is cutting the same branch on which he is sitting.

These are only some of my concerns. There are a few other concerns also, but I see that my watch is inhibiting me to speak further. So, I have to carry the load of other concerns on my head. I shall wait for some other opportunity to make you a partner of my concerns.

Genes, Criminal Behaviour and the Law

SEBASTIAN J PADAYATTY
AND
H. SHARAT CHANDRA

We discuss in this brief article a small but growing area of practical as well as philosophical interest in which genetics, medicine and the law intersect. In doing so, we are conscious of our lack of legal training and our approach to this issue is therefore more from the perspective of science than that of the law.

In criminal law, a person may be held culpable if the court is convinced that the crime was a volitive act, that is, the person purposely and knowingly committed the act. His culpability is established during the trial, at which many types of evidence may be produced. Implicit in holding the accused culpable is the presumption that "human beings possess free will for the most part and the decisions to engage in dissocial behaviour are intellectually and emotionally under the control of the perpetrator" [1]. The autonomy of individual choice is fundamental to criminal law, as it is to the existence of civilized society. In the wider society, and in science, religion and philosophy, free will has a broader and more varied meaning. At one end are those who hold that free will is very limited – religious groups who believe in predestination, and those who put their faith in biological determinism. At the other end are those who champion a virtually unlimited ability for conscious choice. Whereas physical limitations on the exercise of free will are readily recognized, recent findings, primarily in genetics, have raised the contentious question whether conscious thought or voluntary action can be circumscribed by biological factors intrinsic to the individual.

Do genes affect behavior? Clearly they do, in the sense that genes encode sets of behavioral repertoire that enhance survival. But genes are not deterministic, in that a gene does not compel a particular type of behavior but merely increases or decreases the propensity to act in a certain way. Therefore, in traditional legal thinking, genes do not have a major role in determining whether an act is voluntary or not. [2] However, the law is rarely immune from evolving societal norms, and from widely held views on the extent and limitations of free will. Indeed, future debate on the idea of free will is likely to be informed not only by the traditional philosophical and religious arguments, but also by advances in science, especially in neuroscience and genetics.

Criminal trials involve determining guilt, and deciding on suitable punishment. Evidence on the influence of genes on behaviour has been used in courts of law in two distinct areas. One is in the determination of guilt. The second is to establish whether a genetic defect contributes to the evasion or diminution of responsibility. [2] Genetic evidence has been used to argue that criminal defendants are afflicted by certain mutations or gene variants that contributed to the crime. Because the effect of genetic changes on behavior is not deterministic, the argument that a defendant is not guilty because of a genetic condition has not found support. Most cases so far have sought to use genetic evidence as a factor in mitigation because a wider range of evidence is permissible at the sentencing phase, but judges have rarely allowed such evidence even at the sentencing phase. Nevertheless, purported 'genetic defect' has been used as an argument by the defense for involuntariness, usually as contributing to drug or alcohol addiction, under whose influence the crime is said to have been committed.[2]

It may appear at first that a well established relationship between a particular gene and violence, or a family history of violence, somehow diminishes the responsibility of the defendant. Had this been the case, it has been pointed out, we already have an excellent genetic marker for crime,[3] a marker so strongly associated with violent crime that it is unlikely a stronger association will be found. The vast majority of violent crimes are committed by males, all of whom have the Y chromosome. Yet most men never commit any crime, let alone violent crime. In other words, genetics may show statistically that a certain gene increases the probability of a specific type of action but cannot tell how a particular individual will act.[4]

BEHAVIORAL GENETICS AND THE LAW

The idea that crime is inherited was widely held in many parts of the world. In the past, even though the mechanisms of heredity were not known, many crimes were attributed to families or certain (usually marginalized) groups as being caused by their "blood". The idea that crime is hereditary has long roots in India, and is in keeping with the rigidities of the caste system as well the widely-held belief that individuals carry the burden of their sins from their previous births. Entire communities in India were considered criminals, and this belief was formalized during British rule by listing these as "criminal tribes". These tribes were "de-notified" as recently as in 1952. If people indulged in crime over many generations, it may simply be due to the widespread convention of youngsters following their ancestors' means of livelihood ('hereditary profession'). Indeed, many of the "criminal groups" became settled farmers after a successful programme of rehabilitation.[5]

The late 19th century and early 20th century saw the rise of many schools of thought on the hereditary nature of crime. But when the principles of heredity began to be understood, contrary to what one might have expected, ancient prejudices were resurrected under the imprimatur of this new science, especially in the West. One popular idea was that crime was due to "hereditary degeneration" and that it could be discerned in the physical characteristics of the criminal. [6] In the US, the eugenics movement gave impetus to several large-scale, but poorly designed studies whose results were claimed to support theories of genetic causes of severe social dysfunction. These ideas were sufficiently popular to enable the passage of regressive legislation [7,8]. As a consequence, great harm was done, and in several countries groups considered feeble-minded, deformed or criminal were subject to ban on marriages, compulsory sterilization[7] and even euthanasia[8]. Much of this research was later discredited and shown to be unscientific and therefore without value.

XYY AND GENE DOSAGE

Human cells contain 23 pairs of chromosomes: 22 pairs of autosomes and a pair of sex chromosomes, the X and Y. These are numbered according to length, chromosomes 1, 2 and 3 being the longest and 21, 22 and Y being the smallest. The X is a middle-sized chromosome; it occurs as the single copy in males (46, XY) and in two copies in females (46, XX). The Y, which contains an important gene for maleness, is transmitted from father to son. The XYY condition (47, XYY) arises when, due to an error in the distribution of chromosomes, a father transmits to his son two Y chromosomes rather than one.

If the dosage (or the number of copies) of a gene or a chromosome is abnormal relative to that of other genes or chromosomes, it can lead to developmental and physiological anomalies. For instance, the presence of three copies ('trisomy') of chromosome 21, instead of the usual two, results in Down syndrome (47, trisomy 21), a developmental anomaly whose most serious consequence is mental retardation. Trisomy for autosomes other than 13, 18 and 21 do not survive: 40% to 50% of all first trimester abortions are attributable to trisomies and other numerical variations in chromosomes. On the other hand, embryos with an extra X chromosome (47, XXX) survive and come to term. Even tetrasomy for the X chromosome (48, XXXX) is viable because there is an unusual mechanism which leads to the inactivation of all X chromosomes in excess of one and nullifies the deleterious effects of X-chromosome gene dosage imbalance. The presence of an extra Y chromosome also does not affect survival. About one in a thousand men is 47, XYY.

The XYY condition has attracted considerable attention in both scientific and legal circles because of its purported association with criminal behaviour. In 1965, in a study of 197 mentally subnormal male patients with "dangerous, violent or criminal propensities" in a Scottish institution where they were being treated under conditions of special security, Jacobs et al (1965) found that 8 of them (3.5%) had an XYY constitution [9]. This number is significantly higher than that expected by chance. The controversial implication of this study was that a doubling of the dosage of genes on the Y chromosome was somehow related to criminal behaviour.

As noted above, the Y is similar in size to chromosome 21, but a significant amount of its DNA is noncoding and repetitious, with no known functions. As of now it appears that the Y has fewer than 50 genes, whereas chromosome 21 has over 350. In addition to mental retardation, children with trisomy 21 have facial and other dysmorphic features which can be recognized at birth or soon after, whereas XYY children are not readily distinguishable from XY children. Indications of the XYY condition (see below) such as unusual tallness, facial acne and behavioural problems are not usually recognized until adolescence.

Even when the chromosome number is normal, abnormal dosage of a single gene or a segment of a gene can lead to disease and anomalous development. An example is Huntington disease (HD), a neurodegenerative disease which manifests itself in midlife. The disease progression is rapid, with movement abnormalities, personality changes and a gradual loss of cognition, ultimately leading to death. The disease is caused by an abnormal increase in the copy number of a short segment of DNA within the HD gene.

XYY CONSTITUTION AND CRIME

The XYY condition was first reported in 1961. In the 1960's and 1970's several reports were published showing that men who carried an extra Y chromosome were disproportionately represented among criminal prisoners. [9-13] XYY men tend to be very tall [14] and some have slightly reduced intelligence. While the incidence of XYY is roughly one in 1000 men, in many prisons they constituted 1 to 2% of convicted criminals. [15] As additional studies were published, it became obvious that many XYY men lead normal lives, but nevertheless the term 'genetic defect' has come to be used widely in the legal literature in discussions of XYY and such other genetic conditions. It also became apparent that most published surveys suffered from weaknesses, particularly ascertainment bias. [16] In the West the issue became highly charged, stoked by the fear of a revival of the ideas of the eugenics movement which, however discredited and outrageous they may seem now, caused immense harm in the early part of the 20th century. Because of vigorous opposition from scientists concerned with privacy of genetic information, stigmatization of XYY individuals and denial of insurance to them [17], no further studies, especially large-scale studies, have been done. However, case studies of XYY and crime continue to be published [18, 19], but because the initial studies were flawed and drew unwarranted conclusions, much of XYY research remains controversial. In the absence rigorous studies, especially prospective studies of sufficient statistical power, the consequences of the XYY condition to the individual's behaviour remain unclear.[15]

As noted before, the term 'genetic defect' has come to be used widely in the legal literature in discussions of XYY and criminal behavior. But genetic anomalies do not necessarily lead to unpleasant behavior. Individuals with Down syndrome are generally considered to have a pleasant disposition,[20] while those with William's syndrome, another anomalous genetic condition, have been described as possessing a "happy disposition" because they are highly sociable and friendly even to strangers [21,22]. Thus there are genetic changes which may have a positive effect on behavior. Therefore, there is no a priori reason why other, less desirable types of disposition can not be a consequence of particular genetic conditions.

XYY AND CRIMINAL LAW

When the correlation between the XYY condition and crime was published, defense attorneys attempted to use it as exculpatory evidence, [23] mainly in those charged with murder. As early as in 1968, XYY was introduced as evidence in an Australian court but the defendant was acquitted of murder by reason of insanity and not due to the XYY constitution. In 1969, in the first such case in the US, the court allowed evidence of XYY constitution to be presented to the jury (the only US case in which this has been allowed) but the jury found the defendant guilty of murder. In three subsequent murder cases in the US, evidence of XYY constitution was disallowed by the courts. In 1969, in a case in France, the sentence for murder was mitigated because the defendant was XYY, possibly the only time this plea has served the defendant in some way. The same year, a West German court discounted the plea of XYY genotype and sentenced the defendant to life imprisonment for murder. [23] XYY defense has occasionally been used since then, and two such instances (both unsuccessful) were noted in the US between 1994 and 2004. XYY defense may have been used in other countries, but we have not come across any examples in the published scientific literature.

GENE MUTATIONS AND CRIMINAL LAW

In 1994 Stephen Mobley appealed to a U.S. court against his death sentence for murder on the grounds that he should have been tested for genetic defects, because there was a history of violent behaviour in his family going back four generations. However, many family members, including his father, were successful businessmen. Mobley's family was wealthy, and there was no evidence that he had been neglected or abused as a child. He had behavioural problems as a child and showed violent behaviour in his youth. He was at various times charged or convicted of forgery, repeated armed robberies, credit card theft and sexual assault on another prisoner. Mobley robbed a store by holding a gun to the back of the manager's head. He shot the manager as he pleaded for his life. Following capture, Mobley confessed to the crime. Lawyers representing Mobley decided that they had no defense against the charge of murder [24]but claimed that Mobley had a genetic defect that made him violent. They asked that he be checked for chemical abnormalities of the brain, as such changes had been observed in a Dutch family with a violent history (see below). However, citing that Mobley had normal intelligence (unlike members of the Dutch family) and that a genetic relationship to violence was not certain, the court refused to allow genetic testing. The jury found him guilty of murder, and he was executed in 2005 after numerous appeals failed. [24]

MONOAMINE OXIDASE A

Cells in the nervous system transmit impulses from one end of the cell to the other as electric pulses. Where two nerve cells meet, they communicate by means of chemical messengers. The arrival of an electrical impulse triggers the release of a chemical messenger (neurotransmitter) which passes across the small gap that separates the two cells (synapse). On reaching the target cell, the neurotransmitter binds to specific receptors that promote or inhibit the propagation of the signal. Common neurotransmitters in the brain that modulate behavior include Noradrenaline (Norepinephrine), Dopamine and Serotonin. Once secreted into the synapse, some of the neurotransmitter binds to receptors on the nerve cells and are taken up by the cells. Neurotransmitters that remain in the synapse are rapidly destroyed by specific enzymes. Keeping the synapse free of neurotransmitters is an important process because it is only then that the cells are able to send stimulatory or inhibitory signals rapidly. A key enzyme that facilitates this process is Monoamine Oxidase A (MAOA), which destroys Noradrenaline and Serotonin. Drugs that inhibit MAOA are used to treat depression and other brain disorders.

MAOA ACTIVITY AND CRIME

In 1993, a Dutch pedigree with a long history of violence was found to have a mutation in the gene encoding MAOA, which resulted in complete and selective deficiency of MAOA.[25] In this family, several males with borderline mental retardation indulged in violent and impulsive behavior, arson, attempted rape, exhibitionism and attempted suicide. The gene for MAOA is on the X chromosome; therefore, only males in the family were affected. This is the only reported instance in which a mutation in the MAOA gene abolished the activity of the enzyme completely. Norrie's disease, another rare disease of men, has a chromosomal deletion which includes the MAOA gene. These individuals have many problems, including deafness and blindness, so that the effect of the loss of MAOA activity alone is difficult to discern. [26]

When initially published, the results on MAOA were a novel discovery, pointing to a relationship between a defect in a specific gene and violence. The report formed the basis of Mobley's appeal demanding that he be tested for genetic defects. One difference between the Mobley family and this Dutch family was that in the latter impulsive acts of violence were known only among males, but among both men and women in Mobley's family. More recently, 442 men were studied in New Zealand, comparing the expression of the enzyme MAOA with antisocial behaviour, including violence [27, 28]. Certain variations in the DNA sequence of the promoter region of the MAOA gene reduced activity of the enzyme. Gene expression was assessed by analysis of differences in the promoter region of the gene. Outcome was assessed by four different measures of antisocial behavior and convictions for violent crime. These 442 men were among 1037 children who were followed up at regular intervals, starting at age 3 to their 9th follow up at age 26. Because women have two copies of the MAOA gene (one on each X chromosome), and one X chromosome is randomly inactivated, they present a more complicated picture. Further, in general women have low levels of antisocial and violent behavior, and therefore there were not enough cases for investigation. [27] Polymorphisms in the MAOA gene were correlated with various indices of antisocial behavior. It was found that men with low enzyme activity who had been maltreated as children were more likely to commit violent crime. Among those individuals with low MAOA activity and who had also been victims of severe maltreatment in childhood, 85% developed antisocial behavior. [27, 28] Those whose enzyme activity was normal did not develop antisocial behavior even if there had been severe childhood maltreatment. Other studies (but not all) have, to varying extents, supported these findings.[26]

RECENT USE OF BEHAVIORAL GENETIC EVIDENCE IN CRIMINAL LAW

It was thought that the Mobley case had opened the floodgates to the introduction of behavioral genetic evidence in criminal trials, but in fact between 1994 and 2004, a defense based on "genetic defect" was introduced only 27 times in US courts. [24]The majority of these cases carried death penalty and genetic evidence was used not to claim that the defendant was not responsible for the crime (as in an insanity defense) but at the sentencing phase to offer "genetic defect" as a mitigating factor. Though the courts have treated such evidence skeptically, no clear standard for admission of evidence emerged. [24] It is quite possible that in future genetic evidence, while may not by itself be decisive, may be used to support accepted mitigating factors, such as schizophrenia.

In the 27 cases referred to above, most involved death penalty (21), life imprisonment (3) or a long imprisonment of 35 years (1). Unlike evidence presented at the trial to establish guilt, a much broader leeway is given to admission of evidence for mitigation than for defense.[24] Genetic evidence has been used mainly in convictions for murder to mitigate sentence by validating mental illness or other well established mitigating factors. It has been used to claim that the defendant had a genetic predisposition to drug or alcohol addiction, and acted involuntarily under the influence of alcohol or drugs.[29] In this series of 27 cases, the genetic defect claimed included the XYY condition (2), mental illness (16) and alcoholism (4).[24]

A DOUBLE EDGED SWORD

In a criminal case, genetic evidence can be a double edged sword[24]. A genetic abnormality may appear as a valid defense against criminal conviction if it can be shown by established scientific methods that there is a strong association between the abnormality and violent behaviour. If the association is weak, it may serve to mitigate punishment. In this situation, it would be similar to the plea of insanity impairing judgment. However, insanity can be, and sometimes is, self limiting, and can often be treated effectively by medication. Genetic defects are "permanent", in the sense that the DNA in every cell carries the abnormality. For the foreseeable future such abnormalities are incurable, though it is possible that some ill affects may be ameliorated by pharmacotherapy. For the criminal defendant, a claim of genetic abnormality is both an opportunity and a potential danger.[29] The same propensity to, say, violent behaviour, purportedly resulting from a genetic change may be grounds for denial of parole[4] or bail while awaiting trial. Prosecutors may argue that the defendant has an irreversibly violent constitution, and should therefore be imprisoned for a longer period rather than for a shorter period, for the protection of society. If the defendant does not have genetic markers for mental illness or alcoholism, prosecutors may argue that the defendant does not have a psychiatric illness or other disorders as claimed by the defendant. [29]A man not found guilty of murder by reason of insanity may be confined to an institution for the criminally insane for life, or till he is found to be cured or no longer a danger to others. In this instance, his confinement may be longer than that of a man found guilty. Indeed, if a genetic change with a high propensity to violence were found that did invariably lead to violent crime, an argument for preventive detention may be made. Thus, genetic changes may serve the prosecution as well as the defense, though the trend towards medicalizing of crime and behavior may favor the defense. A concern that will need to be addressed is that it may be possible to show that every criminal defendant has some genetic variation which has a possible relationship to antisocial behaviour,[30] and such findings may be used to shield offenders from the consequences of criminal behaviour.

CONCLUDING REMARKS

The rapidity of advances in human genetics is such that more and more behavioral traits that have a strong genetic component are bound to be uncovered. Because such findings will slowly seep into the popular consciousness, and into culture, literature and philosophy, they are likely to modify current concepts of free will. When the genetic foundations of human behavior are sufficiently well understood, it is likely that the law will consider genetic changes leading to altered behavior as mitigating factors akin to some forms of mental illness, without diluting the autonomy of the individual or the concept of free will that are the basis of civil society and individual liberty. Historically public understanding of the biological roots of human behavior has been influenced by unsubstantiated and sometimes fanciful theories [4]. Therefore, in order to enable accurate interpretation of genetic evidence by lawyers, judges and juries, it is essential that expert evidence is based on proven and verifiable facts. In other words, because of the aura of infallibility that sometimes surrounds scientific evidence, what is needed, perhaps even more than sagacity on the part of the judge, is rigour on the part of the scientist.

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Programme

Sunday, 26 March 2006

3.30 pm – 4.00 pm: HIGH TEA

04.00 p.m. – 05.00 p.m	Welcome and Inauguration
Welcome	Dr K Kasturirangan, Director, NIAS, Bangalore
Chairman's Remarks	Dr. Bhalchandra Mungekar, Chairman, Governing Body Council, Indian Institute of Advanced Study, Shimla
Inagural Address	Shri M V Rajasekharan, Hon. Minister of State in the Ministry of Planning, Govt. of India, Delhi
Inagural Address	Shri T N Chaturvedi, His Excellency the Governor of Karnataka
05.00 pm - 06.00pm	Keynote Address Prof. Goverdhan Mehta, *Former Director, IISc, Bangalore* Session 1 Chairperson: Dr M R Srinivasan, *Member, Atomic Energy Commission, Govt. of India*
06.00 p.m. – 07.00 p.m.	S Banerjee, Bhabha Atomic Research Centre, MumbaiApplications of Nuclear Technology for Societal Benefits
07.00 p.m. – 08.00 p.m.	K Kasturirangan, National Institute of Advanced Studies, BangaloreApplications of Space Technology

Monday, 27 March 2006

	Session 1, Chairperson: Prof. Raghavendra Gadagkar, *Chairman, Centre for Contemporary Studies, IISc, Bangalore*
09.30 a.m. – 10.30 a.m.	M S Valiathan, *Manipal Academy of Higher Education, Manipal The Technologic Challenge in Health Care*
10.30 a.m. – 11.30 a.m.	Sukumar Devotta,*National Environmental Engineering Research Institute, Nagpur* Science, Technology and Environment
11.30 a.m. - 12.00 noon	TEA
	Session 2, Chairperson: Prof. R Natarajan, *Former Director, IIT, Chennai*
12.00 noon - 01.00 p.m.	P Rama Rao, International Advanced Research Centre, Hyderabad Challenges in Higher Education in the face of India's Demographic Ascendancy
01.00 p.m. – 02.00 p.m.	LUNCH
02.00 p.m. – 03.00 p.m.	N J Rao, Dept. of Management Studies, Indian Institute of Science, Bangalore Quality of Engineering Education
	Session 3, Chairperson: Dr K N Shankara, *Director, ISRO Satellite Centre, Bangalore*
03.00 p.m. – 04.00 p.m.	V K Aatre, Former Scientific Adviser to the Defence Minister, Govt. of India Emerging Technology of MEMS and Indian Initiatives
04.00 p.m. – 04.30 p.m.	TEA
04.30 p.m. – 05.30 p.m.	N Balakrishnan, Associate Director, Indian Institute of Science, Bangalore Information and Communication Technology and Societal Development

Tuesday, 28 March 2006

	Session 1, Chairperson: Prof. K Vijayraghavan, *Director, NCBS, Bangalore*
09.30 a.m. – 10.30 a.m.	Sharat Chandra, Dept.of Microbiology and Cell Biology, IISc, Bangalore *Some Legal and Ethical Issues in Genetics*
10.30 a.m. – 11.30 a.m.	T S Sridhar, TRIESTA Sciences, Bangalore Impact of Genomic Revolution on Medicine
11.30 a.m. - 12.00 noon	TEA
	Session 2, Chairperson: Prof. Arcot Ramachandran, *Hon. Professor, NIAS, Bangalore*
12.00 noon - 01.00 p.m.	Narasimha D Rao, Indian Institute of Management, Bangalore *Energy Options and Alternatives*
01.00 p.m. – 02.00 p.m.	LUNCH
	Session 3, Chairperson: Prof. B V Subbarayappa, *Former Director, IIWC, Bangalore*
02.00 p.m. – 03.00 p.m.	N Mukunda, Centre for Theoretical Physics, IISc, BangaloreProgrammes for students and teachers- the Science Education initiatives of Indian Academy of SciencesS
03.00 p.m. – 04.00 p.m.	S Kumar, Formerly Professor, University of Chandigarh, Chandigarh The role of a Scientists in Relations to Society
04.00 p.m. – 04.30 p.m.	TEA

*45 minutes presentation + 15 minutes discussion

National Seminar on Science, Technology and Society
26-27 March 2006, NIAS, Bangalore

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